Southern California Edison Company

SCIENTIFIC AMERICAN SUPPLEMENT

Copyright 1918 by Munn & Co., Inc.

VOLUME LXXXVI]
NUMBER 2235

★ NEW YORK, AUGUST 24, 1918 ★

[10 CENTS A COPY
$5.00 A YEAR

LIBRARY
Southern California Edison Company

Photo by Underwood & Underwood

Field workers on a sugar plantation

SUGAR MAKING IN CUBA [See page 120

The Psychology of Color—I*

Color as a Form of Consciousness

By Leonard Thompson Troland, Harvard University

WHEN the committee requested me to present a paper on "The Psychology of Color," it seemed to me that their phraseology was redundant, since from my point of view color appears to be a psychological fact, and a psychological fact only. The word "color," as it is used in popular, as well as in psychological discussions, refers to one of the fundamental qualities out of which our every day experience or consciousness is made up; it is the basic stuff or substance of our visual awareness. The world of seen space, out into which we look, presents itself to us at each moment as a pattern of colors and luminosities, arranged in three dimensions. This world of immediate visual consciousness, freed of the physical interpretations which our laboratory science thrusts upon it, is a subject matter of psychology, and only in this experimental world, so far as we know, does color exist.

Color, considered as a fact of immediate consciousness, must of course, possess causes or conditions, and the science of color is as a matter of fact, more concerned with these conditions than it is with color itself. Thus we know that the normal experience of color in any individual awareness depends upon the stimulation of the eye with radiation comprised of a limited range of wave-lengths, it depends upon the response of the retina, upon the excitation of the optic nerves, and upon the activity of certain parts of the brain. Color thus has its physical and its physiological bases, but these are not themselves color, nor are they colored; and we should be very careful not to confuse them with color.

I have noticed a tendency to employ the word color in studies which deal purely with the objective properties of radiation, and I believe that this usage is undesirable because it conduces to a confusion of issues which really should be kept separate. Planck, for example in his discussion of temperature radiation, constantly uses the word color as a synonym of wave-length. The greater fraction of the radiant wave-lengths with which his theory deals do not even have the power to excite color when they strike the eye, but even those which do possess "visibility" are simple etheric undulations or electromagnetic pulses, and not color. The "black body" radiation curve of an incandescent substance does not *constitute* a color, but merely represents a group of physical stimuli, which when applied to a normal visual organism will *generate* a color.

The confusion of color with the physical stimuli which usually produce it might be pardoned if the relation between actual color and optical stimuli were constant. As a matter of fact the relation, or relations, are far from being rigidly fixed. *Apparent color* is a function of a large number of variables, only one of them being the wave length constitution of the radiation which some object transmits or reflects, or which strikes the retina. Physically, the "color" of rosaniline or methylene blue, is a constant, as it depends upon the chemical constitution of the substances, but the qualities which we experience when we look at these dyes depend not only upon the nature of the radiation which impinges upon them—whether it be "tungsten light" or "daylight"—but also upon the state of adaptation of the eye, the contrast conditions, the visual "type" to which we belong, and even upon what we expect or are accustomed to see under the given conditions.

An illustration of the practical importance of these psychological and physiological variables which influence experienced color can be found in connection with the new "daylight" lamps. If the purpose of these lamps is to reproduce at night the color experiences of daytime, it is certain that we cannot always accomplish this result by supply radiation identical in wave-length composition with sunlight. A show window illuminated by strict artificial daylight, if set in an environment of ordinary "tungsten" or even "nitrogen tungsten" light appears distinctly bluish and cold. And it really is bluish and cold, so far as these terms have any meaning. The color is a result of the reaction of our psycho-physiological organisms, and in attempting to reproduce the color world of our daytime experience, contrast is a variable often more important than wave-length constitution.

Similarly, the state of chromatic adaptation or "tuning" of the visual system must be taken into consideration. If we come suddenly from the "yellow light" of our common artificial illuminants into daylight, artificial or real, the latter will seem unnaturally blue, because the exposure of the eye to the yellow light has raised its relative sensibility to blue. It is not quite correct, moreover, to say that this blueness is an illusion, and consequently to neglect it as of no practical importance. The actual color quality of our experience is blue, whatever may be the constitution of the radiation which is falling upon the retina. This radiation itself has no color at all. If we neglect the level of chromatic adaptation of the eye, in attempting to reproduce the daylight experience, we are passing over a fundamental variable in the equation which determines such experience. Such an effort would be like trying to regulate the pressure of a confined gas merely by changing the volume of the vessel in which it is contained, without considering possible variations in its temperature, which might result from the volume changes themselves.

It is of course true that if we pass from a yellow-illuminated environment into one which is flooded with true daylight, the bluishness which at first was so apparent, rapidly wears off. But this change follows an asymptotic curve of decay; it is never quite complete, and as time goes on the change occurring in each moment becomes less and less. This asymptotic law of color adaptation has many lines of practical application, some of which at first sight may seem logically opposed to each other. In the first place, it implies that the residual effects of the exposure of the retina to "colored light" will persist for a long time. There is good empirical evidence that this persistence increases with the intensity and duration of the exposure. If we have spent an hour in distinctly "yellow light" and then enter a room illuminated by daylight, the bluish appearance of things may continue for a relatively long time. The same effect is produced, of course as a result of wearing amber glasses. Persons who use these glasses habitually as for example in motoring, more often complain of the bluish quality of ordinary daylight than do persons who have never worn yellow lenses.

According to Hering, common daylight is psychologically slightly yellowish. If this is true it means that throughout the day our visual apparatus is being strongly adapted to yellow, so that if we were suddenly to be shown a true white it would appear somewhat bluish. Just what a true white is, physically, we shall consider below. But if the rod-cone or duplicity theory of vision is true—and it is the best-substantiated hypothesis in the whole field of sensory psycho-physiology—the quality of rod or twilight visual experience should be entirely achromatic. Night vision should give us a chiaroscuro of pure grays. Yet it has been asserted repeatedly that rod vision gives us a field which is slightly bluish. Konig considered this appearance to be so striking that he relegated blue vision to the rods entirely and said that the rod-free fovea of the retina was blue-blind, a statement which is positively erroneous. The most reasonable explanation of the blueness of night vision with the rods would seem to lie in Hering's belief that sunlight is psychologically or physiologically yellowish. If, throughout the day, we are being adapted to yellow, the blue after-effect of this exposure should be expected to combine with the neutral gray of evening vision, making the latter somewhat bluish and cold.

Perhaps the most pervasive, if not the most fundamental principle of psychology is that of association, and it has been clearly shown that the workings of this principle can not only modify our imaginations, but can alter the quality of our perceptions and sensations. Long and constant experience has caused us to add to the actual physical data of evening vision a certain amount of blueness, which is subjective in its manufacture but which nevertheless forms an integral part of our visual consciousness. To a certain extent it may be true that simply because we are aware that it is evening, we subtract yellow and add blue to every color which we see, just as we subtract red from a snowy mountain peak illuminted by the setting sun, and thus see it still as white and not as pink snow.

This adaptational and associate blue of evening may then be a factor which should always be taken into consideration in planning artificial lighting which has definite color aims in view. Psychologically, the distribution curve of daylight from an artificial illuminant, may fail to reproduce the color world of day-time experience. Even under the most favorable conditions of contrast and adaptation, such a stimulus may continue to give us a cold and unnatural feeling. For this reason it is quite likely that the common "daylight" lamp, which is a compromise between true daylight and efficiency, may in fact come closer to the reproduction of actual daylight experience than would the strict photometric daylight.

To a person who does not appreciate the importance of association and expectation in determining our experience it may seem absurd to suppose that a maintenance of the wave-length constitution of daylight in evening illumination, could do anything but maintain the visual quality of daylight. It should be borne in mind that strictly speaking it is impracticable to maintain daylight conditions in the evening, since although the wave-length factors might be kept constant, the intensity and uniformity of the illumination would almost inevitably be reduced. Wave-length constitution is only one of the variables in the visual stimulus which affects the color quality of the sensation. Apparent color is also a function of intensity, both absolute and relative. It varies in a most remarkable manner, also, with changes in intensity, when the retina has been adapted to a specific color.

If the eye has been exposed for a fairly long time to a certain color, such as yellow, and then the level of illumination is lowered, the original field of exposure is smeared over with a thick layer of color complementary to that of the original—and still existing—stimulus; in our example, blue. I have studied this very interesting phenomenon in considerable detail, and have called it the *chromatic dimming effect*. The pertinency of this effect to our present discussion lies in the fact that the coming of evening necessarily introduces a dimming in the general illumination, from 1,000 to about 0.1 millilamberts roughly; so that if, as Hering claims, daylight is actually yellowish, evening light although physically of the same quality, should appear bluish, as a result of the chromatic dimming effect.

The problems of color are very closely linked up with those of luminosity, and especially with the conceptions of "white" and "black." Physically, we define a "black body" as one which possesses non-selective absorption, and has an emission curve following a certain equation. The apparent color of this body, of course depends upon its temperature; it will only appear black when its temperature is low, and there will be only one temperature at which it will appear strictly white. Below this temperature it will be yellowish or reddish; above this temperature bluish.

There has been considerable discussion, in connection with colorimetric procedure, concerning the definition of "white light." It seems to me obvious that "white light" or "white" radiation can be defined logically only with reference to the properties or reactions of the normal human visual apparatus. White radiation is radiation which produces the sensation of white, or the achromatic visual quality, whether it be white or some shade of gray. The existence of complementary pairs of colors makes it evident that there must be an infinite number of different combinations of wave-lengths which will produce this sensation, and consequently it becomes desirable to add the further criterion that "white" radiation must have the distribution characteristic of a black body. The tendency to identify white light in this sense with solar radiation, or with black body radiation corresponding as nearly as possible with solar radiation, is based upon the hypothesis that sunlight actually produces the sensation of white. If Hering's assertion, already referred to, is correct this hypothesis cannot be retained.

It is remarkable that the distribution curve of solar radiation, plotted with respect to wave-length shows a maximum closely coinciding in position with that of the human visibility curve, and still more remarkable able that the discrepancy between the positions of the two maxima is such that it can be explained by the cooling off of the sun since that evolutionary period in which the visibility curve was first established in the human species. If it is true, as Hering alleges, that sunlight is slightly yellowish, this fact can be explained by the same cooling off of the sun, on the supposition that coincidence of the maxima of the visibility and a black body radiation curve would normally yield a pure achromatic sensation. In other words, it seems reasonable to believe that color vision is a physiological device by means of which the organism detects a deviation of wave-length distributions from primitive solar distribution, which would be approximately the distribution of a black body at a definite temperature. Consequently it appears to be a commendable suggestion that "white light" be defined, for colorimetric purposes, as radiation having a black body distribution, with its maximum coinciding with that of the cone visibility curve, *viz.*: 555 $\mu\mu$.

Hering's opinion that sunlight is not strictly white, is based more on the results of dimming effect experiments than on direct observation. It is of course recognized by everyone that the sun itself appears yellow, but this

*From the *Transactions of the Illuminating Engineering Society*

appearance can easily be explained as due to contrast with the vast expanse of sky blue in which the sun is always set. However, it is claimed by Hering that if the retina is adapted to sunlight, and the stimulus is then simply dimmed by the proper amount, the result is the production of a distinct blue. The physiological criterion for "white" would thus be that dimming should produce no apparent color, but merely gray. In my own experience I have found this to be a very sensitive test, but I have not as yet been able to apply it to radiation which I knew to have a black body distribution with its maximum at 555 $\mu\mu$.

SOME THEORETICAL COLOR PROBLEMS

It may not be entirely without interest in a paper of this sort to refer to some of the more purely theoretical problems of color vision. In several respects color vision is one of the most mysterious processes of which nature affords us an example. Even when we lay to one side the fundamental mystery of the relation between consciousness and matter, there are a number of aspects of the process which have proven themselves singularly baffling.

The physical spectrum is qualitatively continuous from one end to the other, involving only a progressive change in wave-length. The visible or color spectrum, however, appears to be split up into regions which are qualitatively more or less distinct. This demarcation of colors in the spectrum as it appears to the eye is so definite that early physicists, such as Brewster, Wollaston Goethe, *et al*, could not avoid the idea that there existed a number of distinct kinds of light, red, yellow, green, blue, violet, etc., which were mixed together in different parts of the spectrum in varying proportions. We now know that this relative discontinuity of the visible spectrum is due to the action of the retina or the visual apparatus as a whole, and not to the existence of qualitatively distinct kinds of radiation.

However, this is about as far as we have been able to go, with any feeling of security. We have thus far failed to separate out well authenticated physiological or psychological color units, or to arrive at a clear idea of what the process is by means of which the retino-cerebral mechanism adjusts itself to changes in the wave-length constitution of the stimulus. We can hardly avoid the conviction that the immediate reaction of the retina is a photo-chemical process, and that more than one photo-chemical substance is involved. By color mixture and matching experiments we arrive at the conclusion that at least three such substances must exist, but we have not been able to prove that there are only three, nor have we been able to find any plausible explanation of the antagonistic or complementary relationships of certain pairs of wave-lengths. Theories have been advanced, of course, but they have all failed to achieve that close quantitative contact with experimental results which is demanded for verification.

In order that an animal should be able to make its color discriminations the basis of definite action, the results of these discriminations must be transmitted to the brain centers, and thither, to the motor nerves. Experiments seem to show that stimulation of a single retinal cone can give all of the elementary color experiences, so that it must be possible for the differentiate of all of the specific color reactions to be transmitted along a single nerve fiber. This contradicts the very general principle of "specific nerve energies," which supposes that the excitation of a single nerve can vary only quantitatively and not qualtitatively. Although considerable doubt has been thrown upon this principle in recent years, no one has yet shown how qualtitative differences can be transmitted along a nerve. Sufficient difficulty is being found in endeavoring to explain the manner in which quantitative variations are conducted from the sense organ to the brain.

The problem of identifying, or of selecting *primary colors* is of course closely bound up with the question of the actual mechanism of color vision. Much confusion exists in the discussion of primary colors, and in arguments in which primaries play a part, because of uncertainty or variability in the choice of criteria by which primaries are picked out. There are almost as many different sets of primaries as there are distinct theories of the color process. The Young-Helmholtz theory, as worked out experimentally by Konig and Dieterici, demands three primary colors, an extreme spectral red (mixed with a slight amount of blue), a green (505 $\mu\mu$), and a blue (470 $\mu\mu$). The Hering theory, developed empirically by Westphal, demands an extreme spectral red (again mixed with a slight amount of blue), a yellow (574.5 $\mu\mu$), a green (505.5 $\mu\mu$) and a blue (478.5 pp). The Hering theory also includes black and white as primary colors.

In order to avoid some of the confusion which now exists in the discussions which make use of concepts of primary colors, it would seem to me advisable to define a primary color in a broad way as *one of a small group of colors in terms of which any possible color can be expressed.* Primary colors should be distinguished carefully from *primary visual stimuli*, which might be defined as members of some small group of stimuli in terms of which any possible form of *retinal response* can be expressed. Colors are the qualities of our immediate experience; stimuli are the physical forces which act upon the retina.

If we accept this broad definition of a primary color, it is permissible to develop a number of different sets of primaries, each set capable of entering into formulae which will represent any conceivable color, and determine in its constitution by the conventions which have been adopted for its establishment and use. Thus, the *pigment primaries* are red, yellow and blue, and other colors can be expressed in terms of these by specifying the relative proportions of the primary pigments which are mixed together. The *radiational primaries* of the Young-Helmholtz scheme, on the other hand, must be combined into formulae representing proportions of radiation or of light; while the *psychological primaries* of Hering's system are the reference points of a subjective hue or quality scale. Corresponding with each set of primary colors there will be a set of primary stimuli, or *vice versa*. In the Young-Helmholtz scheme we determine the stimuli experimentally and deduce the colors; in the Hering system the reverse procedure is employed.

In a discussion of the psychology of color, the psychological primaries of the Hering theory should be given more than a passing notice. Physicists and engineers, generally, either are unaware of the existence of this set of primaries or else neglect it as being of no significance, a state of affairs which is not entirely justified. Hering's analysis starts with color itself, considered as a phenomenon of immediate experience; radiant energy and wave-lengths come only as a secondary consideration. He asks the question: "What colors are in our experience qualitatively simple, and what colors appear to be fusions?" He answers with Leonardi da Vinci, Goethe and others, that the simple and unique colors are red, yellow, green, blue, black and white, and that all other experienced visual qualities look like fusions of these qualities in various proportions. Although yellow can be produced by the mixture of red and green lights, it does not *look* like a mixture of red and green, any more than white *looks* like a mixture of red, green and blue.

Considerable time has been spent by psychologists in endeavoring to determine exactly what is meant by the criterion of *simples*, or purity, which is employed in the choice of the psychological primaries. The color orange is not a compound in the sense in which a pattern made up of red and yellow dots is a compound, for the sensation orange is just as homogeneous as is that of red. Some authorities, such as Von Kries, have asserted that this concept of simplicity can be given no definite meaning in its application to the color qualities, and hence that the psychological primaries should be abandoned. My own opinion is that in the selection of these primaries, as in other developments of human thought, concepts have been used which were only half-formed but which nevertheless rested upon real distinctions, and consequently are capable of being made clear-cut, although in this clearing-up process their complexion may be markedly altered. The exact meaning of the term "simplicity" can be developed mathematically from a study of the relations of the color qualities in the spectrum, but the subject is too difficult a one for consideration in the present paper.

I wish, however, to recommend to illuminating engineers who are interested in the problems of color, that they give some attention to the system of the chromatic qualities which Hering and his followers have developed. The purpose of "color in lighting" lies in the visual consciousness; Hering's analysis is based upon a direct study of the elements of this consciousness. The earliest students of color problems based their theories of light upon a subjective classification of the color sensations, and although we now know that, considering the objective factors the understanding of which they had in view, their point of attack was ill-chosen, we can hardly doubt that the facts which attracted their attention are actually relevant to a comprehension of subjective and organic factors, which enter into the ultimate goal of illuminating engineering.

[TO BE CONTINUED]

Permeability of Balloon Fabrics

A GREAT many materials have been suggested for rendering fabric gastight; the great majority of balloon envelopes, however, are made from rubber-coated silk or cotton, usually the latter. For the balloon envelope, two piles of cloth are used with the gastight rubber film between them. The two plies may be placed parallel to each other or one ply may be placed at an angle of 45 degrees; the biased fabric is supposed to offer greater resistance to tearing. Usually from 100 to 130 grams of rubber per square meter are placed between the plies. For protecting the fabric and the gas-retaining rubber film from the action of light, heat, moisture, etc., rubber coatings may be applied on the outside; further protection is sometimes added by coating the inside of the fabric also. Lighter single-ply fabrics are sometimes made for use in ballonets and three-ply fabrics find use in large dirigibles or supply balloons.

Goldbeater's skin finds some application in dirigible balloons of the rigid type. Oiled fabrics of various kinds, as well as fabrics coated with lacquers made from cellulose acetate or nitrate, have been tried. Various coatings have also been applied to rubberized fabrics with a view to rendering them more nearly gastight and increasing their durability. However, none of these has been found entirely successful.

Gas escapes from a balloon envelope through leaks at valves, seams, and imperfections in the fabric, and by passage through the fabric. Hydrogen might pass through the fabric by diffusion through minute holes in a manner similar to the passage of a gas through a porous plate or it might escape by solution in the rubber film with subsequent evaporation from the other side. As a matter of fact, both processes occur simultaneously. The escape of hydrogen through openings in the fabrics is only a case of gas effusion, but the passage of hydrogen through the rubber of the fabric is a very different phenomenon.

Thomas Graham, in 1866, investigated the flow of gases through rubber films and showed that it was a solution phenomenon and not a diffusion phenomenon. If gases passed through rubber films by diffusion through microscopic holes, their relative rates of escape should be approximately inversely proportional to the square roots of their densities. Graham showed, however, that the rates of penetration of different gases bore no relation to their density. He found the relative rates of penetration of rubber by different gases to be as follows:

Nitrogen	1.0
Methane	2.15
Oxygen	2.56
Hydrogen	5.50
Carbon dioxide	13.58

The rate of change of permeability of rubber films with change of temperature is also much greater than can be accounted for by the diffusion theory. These and other facts have shown that gases penetrate rubber by first dissolving in the rubber.

When a rubber-coated balloon fabric is placed in contact with hydrogen on one side and air on the other, the following process is substantially what occurs. Both the hydrogen and the oxygen and nitrogen of the air dissolve in the rubber film and tend to saturate it up to the limits determined by the temperature and by the partial pressure of each gas. Each gas penetrates the rubber film at its characteristic speed, and when it reaches the opposite side of the rubber film the gas evaporates from its solution in the rubber because the partial pressure of the gas in question is substantially zero. More of each gas is dissolved continuously on the first side of the fabric and a dynamic equilibrium is reached which continues so long as fresh air and fresh hydrogen are available at the two surfaces. In this manner hydrogen passes through the rubber to the air side and air passes through to the hydrogen side.—From Technological Paper No. 113 of the Bureau of Standards on Determination of Permeability of Balloon Fabrics, by Junius David Edwards, Asst. Chemist.

Steam from Coke

As a result of the pressing demand for products derived from the carbonization of coal in England large quantities of coke have accumulated, and experiments have been in progress with a view to utilizing this coke for steam purposes. Boiler furnaces built for operation with mechanical stokers are not suitable for burning coke alone; but it has been demonstrated that when a chain grate stoker is used simple modifications enable coke and bituminous coal to be burned together in two or more superposed layers. In its simplest form the apparatus consists of a double feed hopper, the front compartment being arranged to feed upon the grate suitably graded coke in an even layer, the depth or thickness of which is proportioned to the draught available. From the second compartment of the combined feed hopper a layer of bituminous coal slack is fed, the joint thickness of the two layers being regulated by means of a guillotine gate. For use with gas-coke breeze, or other non-bituminous fuel in a state of fine sub-division, which is liable to sift through the grate, a three-compartment feed hopper has been designed, the front compartment of which is used for feeding upon the grate a layer of relatively large sized fuel. This method tends to eliminate loss due to riddling of small fuel through the grate, and also protects the grate from intense local heating.

The Lyre of the Poets

A Small Summer Constellation

By John Candee Dean

STANDING on Mars' Hill in the fading twilight of a June evening, a bright star may be seen in the northeastern sky which by nine o'clock becomes brilliantly conspicuous. It is Vega, sometimes called Lyra from the constellation to which it belongs. As various other stars appear we feel the absolute silence of the great celestial globe as it appears to slowly revolve, and we see how natural it was to conceive the universe to be made up of a series of enfolding crystal spheres, with the earth at their center.

Each sphere was supposed to have a velocity of rotation different from that of its neighbor, but all moved eastward. According to the astronomy of Ptolomy, the nearest and smallest sphere was that of the moon. Next came Mercury, then Venus, etc., the last or outer one was the sphere of the Crystalline Heavens; so that in looking at the fixed stars one was supposed to gaze through seven transparent spheres. How beautiful the superstitions of the Greeks were, with their doctrine of musical celestial harmony, too refined to reach mortal ears.

Euripides said: "Thee I invoke, thou self-created Being who gave birth to Nature and to the whole train of globes encircled with eternal music." This music has been a favorite subject of the poets. Shakespeare said:

"There is not the smallest orb which thou beholdest
But in his motion like an angel sings."

Milton refers to the "Celestial Sirens' harmony, that sits on the enfolded spheres." The constellation of the Lyre is associated with the romantic story of Orpheus, for this is the *lyre* placed in the heavens by Apollo to perpetuate the memory of Orpheus. On the death of Eurydice, as the familiar story runs, Orpheus, with lyre in hand, sought her in the infernal regions. Pluto does not appear to have been such a bad fellow; he was charmed with the masterly strains of music and even permitted Eurydice to follow Orpeus out, provided he would not look back until they emerged. Not only was the king of hell entranced by the strains of music, but Tantalus forgot his thirst and the furies relented. Virgil thus describes the effect produced by the lyric music of Orpheus.

"E'en from the depths of hell the damn'ed advance,
The infernal mansions, nodding, seem to dance;
The gaping three-mouth'd dog forgets to snarl;
The furies harken, and their snakes uncurl;
Ixion seems no more his pain to feel,
But leans attentive on his standing wheel."

The Lyre is a very small constellation containing but twenty-one stars. The latter part of June it is near the zenith at midnight, and in August it is near the zenith at nine o'clock. Its brightest star, Vega, blazes forth with the light of first order. It is the most brilliant star in the northern hemisphere, therefore, there is little danger that the novice will mistake it. It is of a blue white color, indicating high temperature, and is sometimes called the most beautiful star in the sky. We turn our telescope onto it for a minute and it blazes up magnificently with increased blueness and we glimpse a close small companion star.

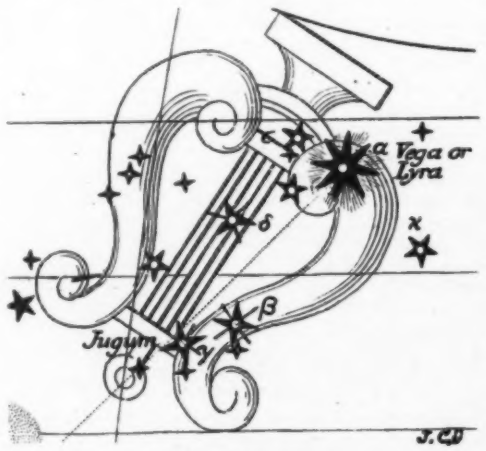
No star in the heavens has attracted more attention than Vega; 12,000 years ago it was the north pole star, and the slow shifting of the celestial pole will, in 12,000 years from now, again bring it near to the pole. Our sun carrying with it all the planets of the solar system is flying toward a point near Vega, called "the apex of the sun's way." The velocity of this movement is 13 miles a second. Mounton estimates that it will take us 558,000 years to pass Vega, but Vega has a motion at right angles to the line of sight which will carry it out of its present position, and although we are now moving nearly in the direction of Vega, we shall not pass very near to that star. It will be 275,000 years before Vega will reach its greatest brightness, and it will then increase but one magnitude, in consequence of our approach.

Astronomers now classify stars in groups, as the botanist does plants and the zoologist animals. Harvard Observatory has classified stars with regard to the nature of their light, as seen in the spectroscope. The principal groups under classification are designated by the letters B-A-F-G-K-M. While the stars are arranged, by their light, in the order given above, it is thought that this classification also indicates the order of their evolution; B stars being the youngest, and the M stars the oldest. B stars have high temperature, M stars relatively low temperature. B stars move slowly and the velocity increases as we pass along A-F-G-K to the M stars. B stars are remote, M stars are nearer. B stars are in or near the Milky way, M stars abhor the Milky Way. B stars are simply in composition, and their complexity increases as we advance to the M stars. Our sun is a G star, and therefore is past middle life. In time it will pass into the stars of class K. Even now the spectrum of the sun spots is like class K.

Vega belongs to class A, and is therefore in its early life. It is supposed to have formerly been a B star, but now by loss of heat has passed to class A, next it will fall to class F and so on down to M; later it may reach the condition of the dull red companion star of Sirius and finally to a black condition like our planets. Integration begins with the hottest stars and there follows a fall of temperature with an increasing complexity of matter, at every stage of stellar development. Here we have an illustration of Herbert Spencer's law, that progress consists in change from the homogeneous to the heterogeneous.

Planetary nebula in Lyra called the Ring nebula

The velocity of light is almost instantaneous. It would pass seven times around the earth in one second. Vega is so remote that it requires 38 years for its light to reach us. When we look at stars in the blue vault of night, we are looking at fiery furnaces. They are gaseous suns of transcendental temperatures, far exceeding any artificial temperature that can be produced by man in his laboratory. Ether waves sent out by the stars bring messages to the earth. The receiving instrument employed by astronomers is the spectroscope. The wit of man has never devised a more wonderful instrument. Messages from the stars come in Nature's lovely prismatic colors. These messages disclose the chemical composition and temperature of the stars, tell whether they are single or double and give their velocity in line of sight.



The Constellation of Lyra

The spectra of Vega reveals intensely hot gases in which hydrogen and helium, the two lightest known gases, are conspicuous, and ultra-violet rays are prominent.

Campbell estimates the brilliancy of Vega at 160 times that of our sun. Its hydrogen-helium spectrum tells of violent motion of its gases. The temperature of a body varies as the square of the amplitude of vibration of its atoms. Increase of heat accelerates atomic motion until a critical velocity is attained which destroys the affinities holding the atoms in chemical combinations. Probably there is a maximum temperature where the violence of motion of the clashing atoms break them up into electrons. Hence a large part of the gases in Vega are probably in the electronic state. Matter in this state is at its lowest point in the evolutionary scale and all progress must be attended with a fall of temperature. If the earth were as near to Vega as it now is to the sun, all terrestrial water would be decomposed by its heat into hydrogen and oxygen gases and the solid surface of our globe would be fused to liquidity.

The public has erroneous ideas about the magnifying power of telescopes. The fixed stars of the heavens are at such exceedingly remote distances that they are practically mathematical points of light. You can not magnify a mathematic point. The brilliancy of stars is increased in proportion to the size of the telescope, but a star like Vega cannot be magnified in size. Even the Lick telescope will not give Vega a sensible surface, nor will the great 100-inch telescope now being erected at Mt. Wilson It is true however, that telescopes show spurious stellar disks, caused by the optical imperfections of the instruments.

There are only two kinds of visible objects outside of the solar system, viz., stars and nebulae. The nebulae are divided into three classes, planetary, spiral and irregular. The constellation of the Lyre contains a very beautiful and easily observed nebula of the planetary class. It was discovered more than 100 years ago, and was called the Ring nebula. Its position is between the stars Beta and Gamma seen near the south end of the western arm of the Lyre. While not visible to the naked eye, it can easily be picked up with a "finder" having a 1¼-inch tube, and is easily seen with an ordinary field glass, but to bring out its details a telescope of good size must be used. This apparent ring of nebulosity is really not a true ring, but an egg-shaped shell of matter which looks like a ring when seen in the background of the sky.

We turn our telescope onto it for a few minutes and note its weird appearance which suggest luminous sparkling vapor in agitation. It appears to be about the size of Jupiter. The light of planetary nebulae shows certain bright lines which betray their gaseous structure and prove them to be self-luminous. There is a tendency by some to return to the theory of Herschel, that the planatory nebulae develop into stars. If we place the planetary nebulae at the head of the Harvard spectral classification of stars, and assume that the planetary is the embrio of the stellar system, we build up a complete theory of stellar evolution. This hypothesis would of course include the solar system. Campbell says that the velocities of the rotating gases in the planetary nebula is sufficient to explain the orbital speed of our great planets Jupiter, Saturn, Uranus and Neptune. He says: "The indications are extremely strong that the planetary nebulae are in general at least as massive as our solar system; many times as massive in some cases, possibly less massive in others. In them we seem to have enough materials to develop into systems comparable in mass with our solar system."

Photographs of the Ring nebula show a bright nucleus in its center which is not visible in the telescope. This is owing to the fact that the light emitted from the nucleus is largely ultra-violet which the eye does not perceive, but to which the photographic plate is very sensitive.

During the year ending in August, 1917, the Ring nebula was photographed 14 times with the 60-inch reflecting telescope at the Mt. Wilson, Cal., observatory, in order to secure plates suitable for determining its distance. The measurements and reductions indicate that its distance is about 800 light years away. It will thus be seen that the nebula is about 20 times as far away from us as Vega. The nebula is oval in form. The diameter of its major axis was computed to be 300 times the diameter of the orbit of Neptune. This would make the Ring nebula about 300 times as large as our whole solar system.

Close to Vega are too mall stars, which with Vega

form an equilateral triangle. The northernmost one is Epsilon, which keen eyes can separate into two stars without optical assistance, and which are easily separated by using an opera glass. A four-inch telescope will show that both stars are close doubles, thus exhibiting a remarkable quadruple system. One turns his telescope again and again, cnto these stars, with undiminished pleasure. The most inexperienced observer is always delighted to see them. Both pairs of this vast system are revolving around their centers of gravity in a period which Young estimates at 300 to 500 years. It is also practically certain that the pairs are also physically connected and are in orbital motion around their center of gravity in a very long period. During the last 100 years this motion has been barely perceptible.

The third star of the small stellar triangle, Zeta, is a wide telescope double star. The star Beta Lyrae was referred to, and its position stated in discussing the Ring nebula. This star is a remarkable multiple, having no less than five companions revolving in orbits. It is also an eclipsing variable star, changing its light more than one magnitude in a period of five days by the eclipsing of the two larger companions. Its smaller companions also produce considerable variation of its light by passing in front of it. While the two larger companions are estimated to be 442 million miles apart and 27 times as large as the sun, they are so remote that no telescope is powerful enough to separate them, and their character is determined wholly by the spectroscopic study of their light. They, like Vega, are very hot, class A stars, with hydrogen, helium, magnesium, spectra.

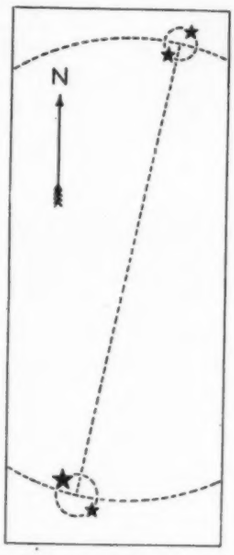
The subject of double and of multiple stars is a great interest. Sir William Herschel was the first to discover that certain pairs of stars were revolving around each other. Some 15,000 pairs of such stars are now known and others are being constantly discovered. They are called binaries. The first discovered were not very close together; now the components of most known binany systems are so close that they can not be seen as separate stars. The period of revolution of binary stars vary from five years to thousands of years. It is remarkable that astronomers are able to calculate the weight of these stars from the size of their orbits and periods of revolution. From the orbits computed, their average distance apart is about equal to the distance of the planet Uranus from the sun; their mass about 3½ times that of the sun, and their brilliancy nearly six times as bright as the sun. It is rather humiliating to humanity to discover that our poor sun generally suffers by comparison with the average star.

The surface temperature of Vega is estimated to be about 20,000° F., while that of the sun is about 10,000° F. The temperature of M stars is about 5,000° F. and finally in the cooler stars the temperature falls to a point which permits the formation of floating crusts of solid matter sailing on a liquid sea of fused materials. Such stars are of a dull red color and are variable in their light. At last they are supposed to pass to burnt-out suns which are dark and invisible. The spectroscope shows that all visible stars and nebulae are composed of terrestrial elements, or substances from which these elements have developed.

The average velocity movement of planetary nebulae is about seven times that of the extremely blue stars of class B. This discrepancy in speed leads to the conclusion that not many stars have developed from planetary nebulae. In fact the indications are that stars are born without motion; hence we must conclude that in general they have been evolved from irregular nebulae and not from planetary nebulae.

From April 20th to 22d annual "showers" of shooting stars, or meteors occur, which radiate from the constellation of Lyra. These meteors are called Lyrids. They are bright but not large.

Astronomy has always been a favorite study of the poets, because it is the most beautiful of the sciences. It is more marvelous and more beautiful than anything the human imagination can produce. The astronomer does not study his art because it is useful but because it delights him to unfold the mysteries of the universe of stars and wring from Nature that knowledge of the cosmos which she so unwillingly discloses.



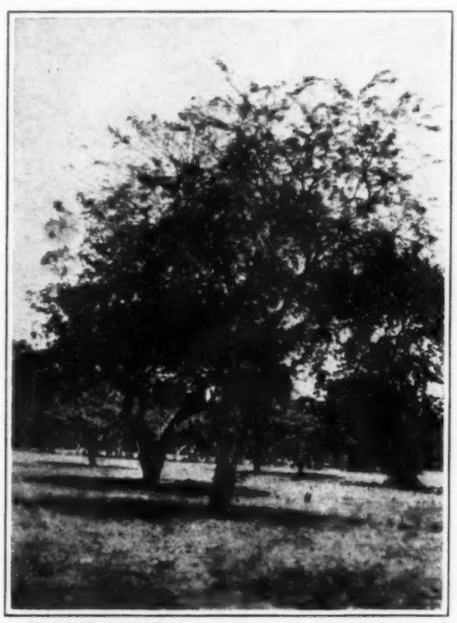
Quadruple system of stars in Lyra. Epsilon Lyra

The Tamarind

By C. D. Mell

THE tamarind (*Tamarindus indica L.*) is a well-known tree in the American tropics, where it is rarely referred to by any other name. While it is true that in literature this tree is occasionally confused with the carob or St. John's bread (*Ceratonia siliqua*), the two trees are entirely different and can be easily distinguished. In height and general appearance the tamarind is more like some of our dry-land loving oaks of the West or our mesquite of the Southwest. It is a large evergreen tree often 80 feet or more in height and sometimes six feet through near the ground. Some writers describe this tree as being one of the most beautiful of the common fruit trees of the tropics. Its crown is large, rounded and somewhat open; the branches are twisted and more or less erect. The trunk is short and thick, and the bark rough and flaky; that of the branches is thick, light and corky. The leaves resemble those of the mesquite, or our common locust, only much smaller. The flowers are pale yellow, formed into small drooping panicle resembling remotely those of our locust, to which the tamarind is related. The fruit is a legume.

The tamarind is not indigenous to tropical America; it is a native of India and southwestern countries of Asia. It was introduced very early in the eighteenth century into Jamaica and from there it was distributed to all parts of the tropical west; it grows abundantly in the islands of the South Sea, and is now thoroughly naturalized in all tropical and even sub-tropical countries of the world. While the tamarind is self-sown in all regions of its growth, especially around cities and towns, it is extensively cultivated for shade and ornament, as well as for its fruit. The tree is suitable for avenue planting, especially in India, where it attains larger sizes and the branches spread more than in the West Indies. There are several varieties of this species; the kind growing in India produces larger and better fruit than that in the other parts of the tropics.



Young Tamarind trees in the park at Puntarenas, Costa Rica

The importance of this tree cannot be overestimated. While the fruits are of prime usefulness, every part of the tree is utilized in one way or another. The fruit is highly esteemed wherever the tree grows, and much of it finds its way into commerce either in the raw or prepared state. The fruit is a pod botanically called legume, which is common to all plants of the pulse or bean family of plants. This pod is from three to six inches in length and from three-fourths to one and a quarter of an inch in width and about one-half as thick. In general aspect it resembles the pods of the common Lima bean, having from one to six or more seeds or beans. It has a grayish and quite brittle outer shell when fully matured, which is easily removed, leaving an acid-flavored, sweetish, pulpy interior in which are imbedded the rather large, flat, square seeds. The pulpy matter has membraneous fibers running through it from end to end. It is this pulpy matter that has the agreeable taste giving the fruit its value as a food and beverage.

The uses to which this pulpy matter are put are almost too numerous to mention. The preparation and sale of this pulp in India constitutes a considerable industry, and quite a business has sprung up in parts of the West Indies and in the Philippine Islands. In the East Indies the pulp is removed from the shell and dried in the sun for home consumption; that intended for export is invariably dried in copper kettles. Salt is usually added to the pulp before drying it, which turns it dark. In this state it is shipped to Europe under the name of natural tamarind. The West Indian kind is called prepared tamarind, which is put up in grades of much less value. In recent years the whole fruits have been imported into the Unietd States. A syrup prepared in Europe occasionally reaches this country. The fruit attains maturity in June, July and August in the West Indies, when the pods should be collected and shipped at once.

In the United States the pulp is used for a number of purposes. A drink is made of it called tamarind, that is known for its cooling effect. It is also employed in flavoring subacid confections, which is probably its chief use. It is reputed to have medicinal virtues, especially in cases of fevers and biliousness, but very little of it is used in this country in a medicinal way. In all hot countries it is used against dysentery, and it is said to be highly serviceable; in a small quantity it acts as an astringent and in large doses as a laxative. Its chief merit is that it has a cooling effect, and for that reason travelers in all hot countries carry it with them to quench their thirst. In Nubia the natives allow the pulp to ferment in the sun, after which it is formed into cakes and dried. This dried mass is then dissolved in water which forms a very refreshing drink. In parts of India a sherbet is prepared from it. By the addition of sugar to the dried pulp and dissolving in water vingear is obtained. In Central America a drink is made by steeping the ripe pulp of the pods in water which is then strained, cooled, and sweetened to the taste. It makes a more palatable and cooling drink than lemonade. The pulp is also an important ingredient of curries and many sauces.

In India the seeds are used for food. They are first roasted and then soaked in water until the thick horny, outer coat comes off. The inner (cotyledons) portion is then boiled, and is said to taste almost like the common garden bean. The young seedlings when about a foot high are relished by the East Indians either in the form of a salad or boiled. The leaves of the trees are used in curries. The flowers are used for coloring food. The wood of this tree is exceedingly durable in contact with the soil and air. It is hard, heavy and very strong, and is highly esteemed by wheelwrights and makers of farming implements. Every part of the tree is useful and it should behoove all land owners in the tropics to plant this tree more extensively, as has been done in the Philippine Islands where owners harvest as much as 350 pounds of fruit from good trees and realize a neat profit of $3.50 per tree per year.

Automatic Lighthouses

DURING the last few years a number of new lighthouses have been built along the coast of Queensland, Australia, inside the Great Barrier Reef, and as life in the tropics is disagreeable even under favorable conditions, it was thougth advisable to eliminate the human side if possible, and accordingly the Aga system of unattended lights was adopted. Acetylene dissolved in acetone at 10 atmospheres pressure is used, and there are ten cylinders, each containing 117 cubic feet, all coupled together. They are changed once a year. The light is turned on and off by a sun-valve, which is so delicate that the light has been seen to come into operation during a rainstorm. A pilot flame is always burning. The lights are of 1,500 candle power, with a visibility of 13 miles. So far—*i. e.*, since 1913—no trouble has been experienced with any of those unattended lights. The first cost compares favorably with that of a manned light, and the running cost is only £30 against £578.

The Oceanographic Work of the Royal Italian Committee

In the present world-wide scantness of food and other necessaries, increasing attention is being directed to the ocean as a source both of food and of other commodities, such as leather, oil, chemical substances, etc. It is correspondingly gratifying to learn that the admirable work done by the Royal Italian Committee on Oceanography has not been definitely interrupted by the war, though some curtailing of its activities was inevitable. We borrow an account of these from a recent number of *Larousse Mensuel*.

This committee, one of the best organized scientific bodies in the world, is familiarly known as the R. C. T. I. from the initial letters of its title *Regio Comitato Tallassografico Italiano*. Its origin was very modest, and dates from 1881, when it was founded by a hydrographic engineer named Magnaghi and Professor Giogli, who made application to the *Academic des Lincei* for means to continue their researches. In 1883 a commission presided over by the well-known scientist Blaserna and composed of members of this academy and of the ministers interested, made an experimental trip on the ship *Washington;* strange to say, however, nothing more of consequence was done until 1908, when the Italian Society for the Progress of Science instituted a provisory committee which met at Rome and at Padua the following year and immediately began, under the auspices of the Minister of Marine, a series of periodic cruises, under the inspiring leadership of Professor Vito Volterra, assisted by various scientists versed in the biology, chemistry, hydrography, etc., of the sea. In 1910 the Italian Government took steps to transform this private committee into a governmental organization, and this was finally accomplished in June, 1913. The scope of its endeavors is indicated in Article 1 of its Constitution:

Art. 1.—The R. C. T. I. is hereby instituted, holding executive functions for the physico-chemical and biological study of the Italian seas, with particular regard to the industries of navigation and fisheries, and for the exploration of the upper atmosphere with respect to aerial navigation.

The Committee will have at its disposal and will administer the following revenues: 1. A government contribution of $12,000 per year; 2. Fixed or temporary contributions of other public administrations, of scientific bodies and of private organizations; 3. The Minister of Marine will provide means of transport for oceanographic cruises and campaigns; 4. A sum of $20,000 is provided for the construction and equipment of a station located at Messina to be known as the *Central Institute of Marine Biology*.

The law provided for the membership of the Committee as follows: A senator and a deputy elected by their colleagues, two delegates from the Italian Society for the Advancement of the Sciences, one from the technical Syndicate of Fisheries, the presidents of the scientific societies and academies contributing to expenses, of the *Magistrato alle Acque*, of the Council of Fisheries, of the Central Meteorological Bureau, of the Hydrographic Institute, of the Naval League, and the directors of the Naval School, the Merchant Marine, and Military Aeronautics, and finally technical experts elected by the Council itself.

The official seat of the Committee is in the Hydrographic Institute at Genoa, but the meetings of the bureau of directors are usually held at Rome in the Ministry of Marine; but a general meeting of the Committee is held yearly in a different city, in connection with the Congress of the Association for the Progress of the Sciences.

The scientific staff of the Committee is composed of specialists in various sciences, with assistants and "preparers" in biology more specially versed in questions pertaining to fisheries.

One of the scientific undertakings which has given most excellent results is the periodical cruises for which the voyage of the *Washington* prepared the way. The object is to study at various seasons of the years at certain definite points, the physico-chemical modifications of sea-water at various depths. Since these observations must be made in accordance with a definite plan rigidly adhered to, the Committee invited the Austro-Hungarian Government to cooperate. . . . An International Commission was appointed, which met several times at Monaco under the presidency of Prince Albert I. It decreed the plan of operation in the Adriatic, determined the longitudinal and transverse lines of that sea to be followed by the ship taking observations, and defined the methods of study of the material collected. This first organization was the germ whence issued a program much more extensive, to be applied to the whole Mediterranean, a program which the present war has naturally caused to be postponed.

Fourteen cruises were made in the Adriatic, regularly every three months, until the summer of 1914. These were made by the ship *Cyclops*, under the auspices of the Italian govenment, and followed a scheme of eight transverse lines. At intervals of 10 marine miles this boat made a "station of the first order," collecting samples of the water at the surface, and at depths of 5, 10, 20, 30, 50, 100, and 200 meters and at the bottom, taking also the corresponding temperatures. Between these "stations" shorter stations were made; everywhere all sorts of fish were caught, plankton was collected, and observations were made in meteorology, upon the gases dissolved in the water, upon its transparency, upon deposits at the bottom, upon currents, etc. The vast quantity of material and of observations collected were distributed among various specialists to be studied, and the results of their researches were published under the title of the *Bulletin of the Permanent International Commission for the Study of the* Adriatic.

In the intervals of the regular cruises accessory ones were undertaken, notably on the coasts of Libya, to study the sponge banks, in the Ionian and Tyrrhenian Seas for the special study of fish, and on the Albanian coast to study the scientific technique of the fishing industry. A special cruise was made, also, to study the damage done to submarine cables by perforating animals.

Other investigations were organized with the littorali waters for their subject. It is generally believed that the Mediterranean is a sea without tides; it is true that at many points on its coastline the tides are not apparent, at any rate to the profane eye; but elsewhere they are very marked, with varied rhythm and amplitude. It is precisely these local variations which it is important to study, and which must be followed not only on the Italian coast, but along the whole Mediterranean littoral. The Committee has heretofore appointed a mareographic commission charged with organizing researches in this line with reference to hydrography, navigation and public works. This commission has installed a mareographic network of the first order, composed of 17 stations, distributed along the Italian Sardinian and Sicilian littoral; observations are made with absolute synchronism at all these stations, and with identical apparatus and methods.

The Committee has also taken the initiative in a complete reorganization of the coastal meteorlogical stations, under the direction of the Hydrographic Institute. It was found necessary to replace superannuated instruments and to induce merchant ships to make precise observations during their voyages. For the benefit of such ships the Committee published a *Manual of Meteorological Observations at Sea* edited by Professor Marini, and organized later a regular service for predicting storms along the coast and on the higher seas and announcing them by wircless.

Another increasingly important service is the exploration of the upper atmosphere; it is designed to centralize and group observations in meteorology and aerology for the benefit of aeronauts. This service is in charge of a Council sitting at Rome but provided with no less than 30 aerologic stations. These send up pilot-balloons, and the results obtained are telegraphed so as to constitute a daily bulleting.

Among the publications issued by the Committee are several monographs on fish (the *Muraenidae* by Grassi, the *Scopelidae* and the *Scombridae* by Sanzo); also an important series of memoirs relating to marine chemistry to fisheries, to the physics and the chemistry of the sea. Among these are notes by Grassi on the tunny, the eel, and the sea-eel; by Sanzo on the larvae of various fish; by Professor de Marchi on the saltness and the temperature of the waters; by Professor de Toni on algae; by Levi Morenoo on Libyan fisheries; by Sella on the sponge banks of Libya and Tunisia. No. 56 in these memoirs has recently appeared. A quarterly bulletin contains accounts of proceedings and official acts, programs of research to be undertaken, short scientific notes, and résumés of oceanographic studies.

MESSINA, "THE PARADISE OF ZOOLOGISTS"

Among all the creations due to the activity of the Royal Committee the magnificent Central Biologic Station recently opened at Messina is particularly to be acclaimed as one of the best organized and most interesting to be found throughout the world. This establishment was inaugurated December 11, 1916, and was thus characterized by the reporter of the International Commission in session at Rome in 1914: "The Committee felt the absolute necessity of a central biologic institute which would permit the execution by suitable means, not only of important studies in marine biology, but a primary examination of biologic material gathered from the sea, and its distribution to different specialists. Its location was long debated. . . . but by a unanimous vote of the biologists the choice fell on Messina, called the Paradidse of Zoologists."

We must here explain the very curious reason for the vaunted richness of the Messina fauna, which has given it a universal reputation among naturalists. Examination of the bathymetric chart of the Italian sea immediately shows two vast pits or valleys. The Mediterranean here attains its two maximum depths: the Tyrrhenian pit at the north of Sicily, the Ionian pit at the southeast. The first is nearly at the center of the great triangle formed by Corsica and Sardinia on the west, the Italian coast on the east, Sicily and Calabria on the south. The second occupies the area bounded on the north by Calabria and the entrance to the Adriatic, on the south by the African coast, on the east by Greece and Crete. The first exceeds 3,500 meters, and the second 4,440 meters, which is the maximum now known in the Mediterranean. But these two seas are completely separated except for the narrow channel known as the Strait of Messina. This arrangement forms two funnels connected by their exit tubes, at the narrowest portion of which are situated Messina and Reggio of Calabria. Between these two cities the submarine earth rises abruptly into a ridge, not more than a hundred meters below the surface. Four times a day, twice in each direction, a violent current, due probably to the Mediterranean tide, rushes alternately from the northern to the southern funnel and vice versa. It flings itself against the submarine ridge, which forces it upward. It thus arrives at the surface where it forms huge whirlpools. These currents bring with them to the surface animals which float at vast depths. When we remember the pains at which naturalists have been for half a century to procure rare specimens from the deep seas, the many ships they have employed, the money spent on cruises, we can comprehend their delight in finding here, in perfect condition and in great numbers, many of the mysterious creatures which are so difficult to catch and which they commonly procure dead and in bad condition. It is a joy to the biologist to behold these creatures of the abyssa perfectly intact and living in the aquariums of the station; they bear small resemblance to the ordinary disfigured specimen preserved in alcohol. In good weather nothing is simpler than to capture them at the very entrance to the port of Messina by using a small boat and a hand net. To this rich fauna, so highly specialized, must be added the throng of creatures which live normally at the surface; the south wind, or sirocco, drives them into the funnel of the strait, where they are captured in large numbers.

It is easy enough for a naturalist specializing in marine fauna to separate those which come from vast depths from those which live near the surface. Animals which live in abysmal depths possess certain well defined characteristics, of which the following are the principal; many of them possess luminous organs; these consist of tiny lanterns whose rays are projected by crystalline lenses and silvered reflectors. Sometimes a thin translucent film is interposed in front of the source of light, causing it to become green, red, yellow or blue at the will of the animal.

Such apparatus is always placed under the ventral skin of the body; but certain fishes possess it within the mouth, behind a formidable row of teeth, which act like a wolf-trap baited by the light. Such organs are oftenest possessed by fish, cephalopods and crustaceans; they are both rarer and simpler in the other groups of marine animals.

These bathypelagic animals are often as transparent as crystal; such is the celebrated larva of the eel, which resembles a sheet of glass and which has no correspondence of form with that which it assumes after its transformation. These larvae pullulate in the Mediterranean, where they are found in company with other fish of the same family. It often occurs that animals coming from a vast depth, fishes especially, are covered with a silvered, bronze or golden cuirass; the skin may be red, brown, black or steel blue, giving them a highly specific aspect.

Our knowledge of the life of these creatures is thus far very rudimentary since at present we possess only rare specimens which are nearly always dead or injured by the apparatus which brings them up from vast depths. It is precisely this which gives its unique value to the Messina station, so placed as to procure these creatures of the abyss living instead of dead.

The station has been built according to a general plan adopted in Messina since the earthquake of 1909; a ground floor and low top story, all of reinforced cement. All of new Messina, rising beside the ruins of the ancient city, is constructed in this prescribed mode. It is situated on a semicircular strip of land, whose concavity encloses the port of Messina and whose convexity faces the strait, opposite the marvelous coast of Calabria. The laboratories are therefore within easy reach of their boats, sheltered in the port, and also of the currents which bring the creatures in question to within a few yards of the entrance of the station. The ground floor is entirely occupied by work rooms, where each naturalist

has, beside a convenient bureau, aquariums fed by a continuous current of sea water. The light in this part of the world is dazzling, permitting the most delicate photographs to be made. Beside the laboratories there are installed collections, offices and library. The first story is devoted to the lodging of the personnel. The basement is arranged in storerooms for glassware, fishing implements, collections of animals preserved for later study, etc. Electric pumps bring the sea water into vast basins where it is allowed to settle and then is distributed by ingenious systems of pipes into the aquariums, where it is projected by pressure so as to carry with it the necessary air supply.

The boats used are of 450 tons and 900 H.P., provided with the required apparatus for scientific exploration. The Committee also possesses a flat bottomed boat of very light draft for research in the Adriatic, specially arranged to permit delicate work even in a rough sea, as well as canoes, etc., for work in the port and strait. The director is the eminent oceanographist, Professor Lanzo; he has two assistants and two "preparers."

The Committee is in reality the head of a vast international enterprise, projecting the study of the entire Mediterranean. This sea, for centuries the center of civilization, strange to say is still imperfectly known for the oceanographic point of view. The solving of the complex problems it presents would have important economic and industrial, as well as scientific consequences. Moreover, it would furnish the occasion for bringing in contact with each other the savants and the industrials of the Latin countries, and who are too often ignorant of each other's work and unable to derive advantage by uniting their discoveries.

The execution of this great international plan is the objective of the Royal Italian Committee under the leadership of the Prince of Monaco. . . . It met at Monaco in 1910, on the occasion of the inauguration of the Oceanographic Museum. In February, 1914, a new session of the provisory commission then formed was held at Rome in the Academy of the Lincei. The countries represented were Italy, Austria-Hungary, Spain, France, Greece, Tunisia, and the Principality of Monaco. . . . It was arranged that the delegates should take the necessary steps on their return to obtain the indispensable powers from their respective governments to sign definite agreements in a plenary reunion of the international commission. This was to take place in May, 1915, in Madrid. Each of the interested countries was to undertake financial participation in the agreed-on work, and to furnish a boat with the required personnel for three consecutive years, beginning January 1st, 1916. The central office of this International Mediterranean Commission was to be at Monaco, presided over by the Prince of that country, who designated Dr. Richard as the General Secretary. . . . The outbreak of the war postponed the execution of these plans till happier days. The conference at Madrid has been adjoutned *sine die*. But the preparatory work is still going on in Italy and in Spain. Besides the cruises above referred to by the ship of R. C. T. I. the Spanish ship, *Núnes de Balboa*, has begun its explorations especially in the Strait of Gibraltar; everything is ready in these two countries to begin work as soon as peace is signed. It is impossible, unfortunately, to say as much of France, though she owes it to herself to respond to the invitation of the Royal Italian Committee.

Dust Inhalation in Mines

Effects on Health

In a paper read at the general meeting of the Institution of Mining Engineers, Dr. J. S. Haldane discussed the conditions under which miners suffer injurious effects from the inhalation of dust.

There is no evidence, the author stated, in the mortality returns for either young or old miners that dust-inhalation has hitherto caused appreciable danger to life in British coal mining, but the widespread introduction of stone-dusting as a thoroughly practical and effective means of preventing coal dust explosions has directed new attention to the possibility of injurious effects. Such effects have hitherto been observed only where hard rock is mined, and practically speaking only when the rock is quartz or stone, such as granite, containing quartz.

The natural inference from observations on miners and others exposed to dust from various forms of quartz or crystalline silica would seem to be that dust-inhalation is dangerous in proportion to the amount of quartz or silica inhaled. This was the author's belief until a few years ago, but his opinions were much shaken by observations made in the course of work for the Royal Commission on Metalliferous Mines and Quarries. Although when stone-dusting with shale dust was first introduced by Sir William Garforth it was generally believed that the shale contained practically no crystalline silica, but only silicates, 35 per cent of quartz was found in the Altofts shale in 1913. The statistical evidence, however, shows clearly that inhalation of shale dust is harmless in practice, and it is evident that for generations all coal miners must have inhaled a great deal of stone dust and therefore of crystalline silica. The stone adjacent to the Nottingham coal seams is often full of crystalline silica; yet the death-rate from lung diseases among miners in the Nottingham and Derby district is, at all ages up to 55, not only, as with all coal miners in England, far below the average for other employments, but is even slightly lower than for farm laborers. But among metalliferous miners in Cornwall the corresponding death rate from lung disease was found to be, at middle age, about 15 times as great as among the Nottingham miners, and more than 30 times as great as their accidental death-rate. At the Mysore mines, where the gold is in quartz, there is little trouble from affections attributable to dust, and in Western Australia there appears also to be only a moderate amount of trouble. In the Transvaal, on the other hand, the trouble has been of the most formidable kind, necessitating extremely drastic preventive measures.

The matter was so mysterious that it seemed desirable to try to clear it up by experiments on animals. From such experiments it appears that dust-particles of any kind (except perhaps when they are soluble and chemically harmless) will cause inflammatory changes in the lungs if enough are inhaled. The finest dust will cause harm if it is in sufficient amount, and this harm, if caused immediately, seems to be much about the same with all sorts of dust. But if the harm is not caused immediately there is a great difference in the effects. Certain dusts, and notably any unmixed forms of crystalline silica, cause lasting and cumulative injury; whereas others, notably coal dust and shale dust, cause no cumulative injury, and no injury at all unless they are present in enormous amounts.

The experiments show clearly what happens to the dust within the lungs in these two cases. When the animals were exposed to as nearly as possible equal quantities of the fine dusts and for equal times, the dusts were found, at the end of the period of exposure, to be abundantly present in the lungs. With coal dust there was special abundance. But some weeks later the coal dust and shale dust lungs were found to be clearing up, but there was no evident diminution of the dust in the lungs of animals which had been exposed to powdered flint or quartzite dust from a Transvaal gold mine. After several months the coal dust and shale dust has entirely disappeared, but the flint and quartzite were nearly as abundant in the lungs as immediately after exposure to the dust. Examination showed that all the dust particles are taken up into the protoplasm of certain of the epithelial cells lining the air cavities of the lungs, and in the case of coal dust or shale dust these cells detach themselves and wander away with their load of dust particles. In the case of the flint or quartzite dust nearly all the dust remains *in situ*, and the cells wander out with it only to a comparatively small extent. Thus, as fast as the dust goes day by day into the coal miner's lungs, it is carried out again by the dust-collecting cells, whereas with the miner breathing quartzite dust the dust for the most part remains in the lungs, and there tends to accumulate from month to month and year to year.

Why is coal or shale dust easily removed from the lungs, but not siliceous dust, and why is pure quartz so difficult to remove, whereas the large proportion of quartz in shale dust is removed quite easily? If the danger were due to mere hardness or sharpness, crystalline dust, even when mixed with other dust, might be expected to be dangerous; yet the quartz in shale and other hard stone is actually harmless in practice. The mere chemical composition of the stone does not seem to matter, but a quality in the dust that does seem to matter is its power of absorbing other substances. Particles of coal dust and other insoluble carbonaceous matter possess this property in high degree, and it is possessed in a less degree by such substances as shale; but crystalline substances, like quartz, seem to have very little absorptive power. Now it can well be imagined that insoluble dust particles are attractive and stimulating to dust-collecting cells in proportion to the soluble substances absorbed in the dust particles, and that particles containing little of these substances will be correspondingly unstimulating.

As regards the second question, the particles of quartz are taken up by the dust-collecting cells, though these do not readily wander out with them. But if enough of the juicy adsorbent particles are also present they will stimulate the cells sufficiently, and consequently the whole of the dust, including the quartz, will be removed. In this way it can be seen how a mixture of quartz with silicates, as in shale dust and the dust from many hard stones, causes no harm. It can also be seen why the dust in the Transvaal gold mines is so much more harmful than in some other districts, where the metal mined is also in quartz. In the Transvaal both the gold-bearing reef and the surrounding country rock is quartzite and the quartz dust is thus very pure. In Mysore, on the contrary, the country rock is not quartzite, and the dust is therefore a mixture containing probably enough of the stimulating dust to stir the dust-collecting cells to activity.

Mr. Mavrogordato made some experiments in which coal dust was added to the flint dust breathed by the animals, and the results indicated that practically the whole of the flint dust was got rid of in a moderate time. The extension of these experiments had to be postponed owing to war work, but the facts ascertained point to the possibility of attacking the problem of dangerous stone dust in mines and elsewhere from a new side and in a manner strangely similar to that in which Sir William Garforth attacked the coal-dust problem. If the inhalation of dangerous stone dust cannot entirely be prevented, its effects can apparently be neutralized by causing another kind of dust to be inhaled along with it. Dust from pulverized clay or shale, or a mixture of coal dust with shale dust, might be specially suitable, as it would be easily visible and could not explode. The most suitable method of applying it would have to be carefully thought out, to ensure that enough of it were breathed; but practical success should be reached, particularly if existing precautions against inhaling quartz dust were rigorously maintained. It is surprising that the flue dust which has been used at some collieries for stone dusting is not readily eliminated, and would probably, therefore, be dangerous if inhaled without admixture; but it seems almost certain that breathed along with coal dust it would be practically harmless. So far as coal mining is concerned, the results of the investigation are fortunately very reassuring. So long as the dust in a coal mine is not explosive, and is not breathed in excessive quantities, it seems to do no harm, and possibly even does some good.—*London Times Engineering Supplement.*

New Disinfection Process for Ships

The disinfection of plague infected ships is a serious problem, and even when there is no suspicion of plague, the task of killing all the vermin and low organisms that foul a ship and its cargo, is no easy task. The disinfection is usually performed with the aid of sulphur dioxide by the Clayton or some other process. Sulphur dioxide has the merit that nothing alive will withstand it, even bacteria, and that it is, in spite of this, only moderately poisonous to man. On the other hand, the SO_2 cannot be applied to certain cargoes, such as grain, wheat, oil seeds, etc., because it deprives them of their germinating power. Some years ago, the Nocht-Giemsa process was introduced, especially for killing rats; in this case the agent is carbon monoxide. The gas is fatal to rats and mice, but is fatal also to man, without giving warning by its smell, as the SO does, while it does not even destroy fleas, not to speak of bacteria, though it does not spoil grain cargoes either. At Stettin, we see from the *Zeitschrift des Vereines Deutscher Ingenieure*, of March 30th, 1918, the medical authorities have recently constructed for the harbor service a disinfecting-ship, in which the two processes are combined. The Nocht-Giemsa gas is prepared by burning coke with an insufficient supply of air, and consists of carbon dioxide, carbon monoxide, and nitrogen. The first plant built for this purpose had done good service in rat-infected buildings and vessels, but was not much wanted owing to the limitations of its powers. On the new steamer, which has a length of 30 m. and 5.4 m. beam, and is built with two bulkheads, the gas generator has a diameter of 2,450 mm. and a height of 2,380 mm., and is capable of supplying 3,000 cubic meters of a gas (containing from 5 to 8 per cent of CO) per hour. The gas is distributed from a 180-mm. main, running along the port side, to the 10 nozzles to which rubber hoses, 75 mm. in diameter can be joined. The sulphur for the SO_2 plant is melted in an oil bath at 160 deg. C., when it forms a mobile liquid (it turns viscous at higher temperature), and the liquid sulphur drops in to the furnace through a regulating valve; the SO_2 gas is cooled before use. The ship is so constructed that the two gases can be used separately or combined; in what proportion they are mixed in the latter case is not stated; there is little experience, so far, probably.—*Engineering.*

A New Heat-Insulating Material

A new heat insulating material, composed of a mixture of a special clay and cork, has been discovered by a Norwegian engineer. The clay and cork mixture is burnt, and the result is the formation of a very light substance that is said to be eminently suitablefor all heat insulating purposes.

Photos by The Gilliams Service

Sugar cane ready for harvesting

A Cuban sugar mill

Sugar Making in Cuba

One of the World's Great Sources of Supply

SINCE Uncle Sam entered the great world's war, and the people of this country have been upon a voluntary rationing system in reference to some of the articles of our daily diet, we have heard more about sugar, and the need of reducing our consumption of the same, than of any other food item with the possible exception of wheat.

The United States Food Administration has placed the country on a sugar ration basis, a measure regarded as necessary in order to prevent a serious sugar scarcity. Some of the factors which have contributed to the decrease in available sugar stocks for domestic consumption are the recent demand for the exportation of more sugar to France, because of the capture of the greater part of the French beet sugar area by the enemy; lack of shipping, due to the troop movement, and loss of many million pounds by submarine sinkings.

The sugar situation would have been undoubtedly very much more serious if it had not been for the very strenuous efforts of the sugar planters of the little island of republic to the south of us, Cuba, who have undoubtedly saved the day for American housewives, as well as those of our Allies, who are now almost entirely dependent upon imports from this side of the Atlantic for their sugar supply.

The Cuban sugar harvest this year is reported to amount to about 3,250,000 tons, but if given a little time Cuba could do even better. The only reason she has not long before this is the competition of beet sugar, grown in various parts of the world, which, on account of low prices, has made bumper sugar crops in Cuba unprofitable. To a very great extent, however, the war has put an end to the beet sugar industry for the time being at least; so now is Cuba's opportunity, and nothing else grows and flourishes in the island republic so easily and surely as sugar cane.

A piece of cane with a knot in it, stuck in the virgin soil from which the forest trees have been merely burned off, comes up seven to ten feet high, and replanting may not be needful for ten years. Sun and rain in the right proportion do the rest. There must be weeding or cultivating, of course, in the early stages of the growth, but afterward the spreading green leaves protect the roots.

While sugar cane grows in Cuba almost as readily as weeds, at the same time the making of the crop is by no means an easy task. This year the difficulties of obtaining labor for field and factory were many, in spite of high rates, and often because of them. The native laborers, black and white, getting three and four times the wages of "before the war," could seldom be induced to work for more than three days at a time. Now there is just so much time to make the crop. The cane is really ripe for cutting at the beginning of the year, and does not hold its full sucrose content much after April or early May, and days lost in cutting cannot be wholly made up afterward.

The great difficulty in solving the labor problem is that only the natives develop real skill in cane cutting. It is little short of sleight of hand the way they strike the machete close to the ground, turning over the falling cane, chop off the top or carolla, cut the sugar-containing piece in three parts, sending the two last pieces flying to the cane heaps as they are severed. Newcomers cannot imitate them. So they hold themselves much as the toreador does in old Spain, a proud personage of skill with a piece of steel. When he wants a week off he takes it with three days pay in hand. To keep them in hand all sorts of devices had to be adopted. Help was imported from Jamaica, black men speaking English with an Irish intonation; Haytien negroes speaking an extraordinary French, San Dominicans speaking a queer variety of Spanish, Canary Islanders also Spanish, a limited number from Spain and lastly a good many Chinese. The other West Indians cannot endure the hard field work, though willing enough, until they are "fed up." This means a good meat diet. The Chinese work steadily at the lighter jobs, but the Canarios and Spaniards are inclined to desert the field work and get to the towns. All this makes serious difficulties for the planters.

Cutting and carting sugar cane

Then the island rail transportation is not adequate. Under war conditions in the United States and Europe new locomotives and new cars are all but impossible, however long ordered. Hence a constant call for engines and cane cars went up all over the Cuban provinces this spring. Larger and larger grow the plantings, which means going further and further afield to bring the cut cane to the mill. As the capacity of the mills increases this necessity grows, and economy advances making the mills grind increasing quantities. The old, slow picturesque bull wagon on two great creaking wheels, drawn by six oxen, can only be used for short hauls. To meet this all the large plantations have private railroads, largely narrow gauge, laid all over their territory, but it is still necessary to use the island's trunk lines for cane that, in the western provinces at any rate, must often be hauled as far as forty miles. To see an administrator in the occasional hours when he must stop his tremendous mill for a shortage of cane is to witness a distraught personage. He blows and blows a great siren that is heard for miles; he telephones, telegraphs, shouts to heaven, plays the madman with great realism and is only appeased when he sees a string of cane cars coming around the curve with a laboring old locomotive sending up a pillar of black smoke.

In the mills themselves a great transformation is in progress, and pining for new machinery or missing parts is another trouble. The old pattern of mill with one pair of cylinders is as out of date. They are now "tandems"—namely a crusher and three, four or even five sets of three rollers, one after the other. After the second set a stream of water is sprayed on the moving crushed cane, dissolving out more hidden crystals and adding to the river of turbid juice squeezed out between the enormous rollers. Progress and change are the order of the day with all the rest of the processes of liming, defecating, evaporating, and crystallizing until after some twenty-four hours the light brown crystals from the centrifugals pour down into the bags of 325 pounds each. Two and sometimes three tandems are found in many of the great mills. And night and day they work the week days through, stopping generally on Sundays to clean up. To see a great mill chew up twenty big car loads of cane, some seven tons each, in less than three hours is a stimulating sight.

A great plantation may have 30,000 acres or more, owned or leased, planted in cane wherever cane can grow. It needs great sums of money to handle such a plantation. The farmer, or colona, as he is called is quite a personage and may have from 1,500 acres of cane upward. He directs an army of labor, has bookkeepers and offices and weighing stations, oxen, and often a fine house. In most cases he borrows largely, gets big advances from the company and takes his pay in sugar or its money equivalent, the latter generally now on a system of averages. Hence he fattens on high priced sugar.

In the western provinces, from which sugar growing has spread eastward, there is much competition for the cane not grown on company land. Hence the company pays higher there for it. Even in the newer eastern lands the

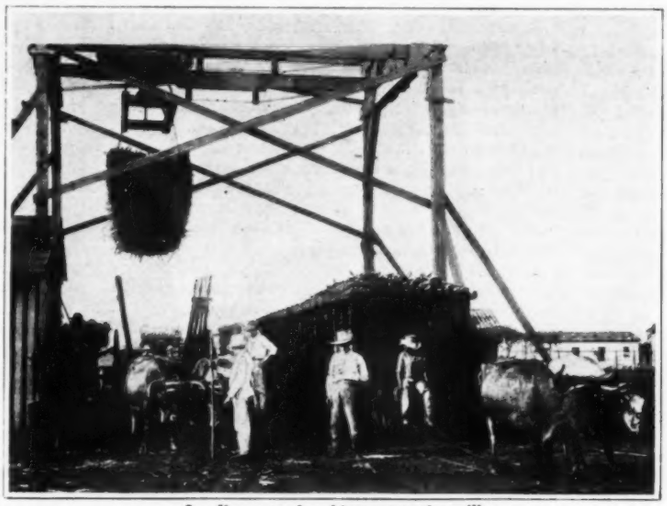
enlargement of the mills is working in the same direction, for mill capacity means more cane. On some of the great eastern estates they own more acreage than they will need for twenty years, but generally the pressure of cane want is felt already.

One of the greatest terrors on the sugar plantation is cane burning. This year it has not been as troublesome as it was last as there have been but few fires. When the fire alarm is given every one turns out to fight it, and the horsemen galloping from all directions toward the swift, terrible flames and vast smoke cloud make a stirring sight. Every one is a fireman on a sugar plantation, and for refusing to fight cane burning fires, Cuba imposes a fine of $1,000 and 20 years imprisonment—no wonder the natives have developed into some fire fighters.

America's share in the sugar business of Cuba is very large and growing. There are 69 mills classed as American, but their output will total a good half of the 3,250,000 tons of 1918. In the mills and fields of American ownership progress is a meaning word. New and improved installations are taking on continually. They are making all the sugar they can, but are getting ready for the days of lean prices that will follow the war. In that world to come of outside competition only the strongest, best financed, cheapest run properties will continue to make profit. Where American interests total at least two hundred millions the greatest efforts to sustain the investment is called for. That means large outlay for new machinery, rails, engines, cars and cane fields.

The old saying that it is an ill wind that blows nobody good holds in reference to Cuba. The war by creating a large demand for Cuban sugar, has been a great benefit to the country, and Cubans are growing wealthy. The signs of social and economic advance are visible all over the island, down to the humblest of the people. The millions flowing yearly to the island in exchange for sugar are reaching them all, as they must since labor makes so much of the cost of making sugar.

Undoubtedly the native Spaniards still hold their preponderant grip upon the old established commercial and mercantile concerns, but the Cubans on their sugar profits are now getting a foothold in the business of the towns. Out of 200 centrals grinding this season 89 mills were cited as Cuban owned. They are generally the smaller mills and least developed, but they are all making money.



Loading cane for shipment to the mill

German Aeroplane Design

TRIPLANE AND BOMBER

Some interesting information about the construction of two types of German aeroplane—a Fokker triplane and a Friedrichshafen bomber—is given in two reports prepared by the Technical Department of the Department of Aircraft Production of the Ministry of Munitions.

In outline design the former machine is somewhat similar to the Sopwith triplane and is in general of orthodox type. The upper plane, which alone is provided with ailerons, measures 23 feet 7 inches over all, while the span of the middle plane is 20 feet 6 inches, and that of the lower one 18 feet 9 inches. The machine is of recent construction, being dated October 20, 1917, but it is characterized as one of the poorest of modern German designs.

While the absence of external bracing wires is noted as an outstanding feature, the chief interest of the machine is said to lie in the constructional design. The unique twin-spar consists of two box-section tapering spars joined by transverse ply-wood. The fore and aft shear strength of this built-up member appears to be supplied by one port and one starboard bulkhead of ply-wood in each plane. This seems inadequate, especially in a high-speed machine, even if the possibility of buckling of the laterally unstabilized ply-wood in nose-diving is disregarded. The structure of the main cellule is a typical example of the price paid for reduction of resistance. Interplane wiring is dispensed with, and structurally the main frame may be regarded as consisting of three pairs of cantilevers, tied by pseudo-struts near the wing tips. The function of these appears to be that of ties which partially distribute the load from plane to plane. Their section is such that they can hardly be expected to withstand reverse leading, and this fact may be one explanation of the bad name which the Fokker has earned by breakage in the air.

The report remarks that on broad lines little good can be said of the Fokker structure. The designer appears to have employed considerable ingenuity (or exhibited considerable mental slackness) in devising schemes whereby slight increase of manufacturing speed has been purchased at the expense of grave structural weakness or increased weight. When speed of production has not tempted him his aim has been reduction of resistance. Here, also, strength—and above all permanence of structure rigidity—has been disregarded, and yet it is hard to see what notable gain of "fineness" has been attained.

CONSTRUCTION OF THE BOMBER

In the report on the Friedrichshafen bomber the construction is described in fuller detail and there is much less adverse criticism. This machine also appears to be of recent construction; different dates are marked on different parts, but that on the tail is January 14th last. It was shot down by anti-aircraft fire at Isbergues on February 16th. It then carried its full complement of four persons—pilot, fore-gunner, after-gunner and bomber. The number of the crew is, however, known to vary considerably, and some machines of the type have carried only two persons. The accommodation is so arranged that the members of the crew can easily change places, all the cockpits being intercommunicating.

This biplane has a span of 78 feet, and the "weight empty" painted on the side of the body is 5,929 pounds the "useful load" being 2,717 pounds and the "permissible total weight" 8,646 pounds. The machine is built up on a central section, to which are attached the forward and rearward portions of the fuselage and the main planes. This central section comprises the main cell or cabin of the body, containing the tanks, bombs, etc., and also embraces the engines and the central portion of the upper and lower planes. The latter, together with the engine struts, are largely built up of steel tube, as also is the landing gear. The central portion of the body, measuring 4 feet across by 4 feet 3 inches in height, consists of a box formation made of ply-wood, strengthened by longerons and diagonals and stiffened transversely by ply-wood bulkheads. The bulkhead farthest forward acts as an instrument board, and behind it side by side are the seats of the pilot and his assistant. The former has a fixed upholstered seat, while that of the latter is folding, consisting of a light steel tubular framework with a webbing back rest. The lower main petrol tank, holding about 60 gallons, is underneath these two seats. Behind this cockpit the body is roofed in with ply-wood, the rear part of the roofing being detachable so as to give access to the second main petrol tank, also with a capacity of about 60 gallons, which is at the rear end of the main body section. In this way a small cabin or covered passageway is provided, at each side of which are the racks for the smaller bombs. Considerable use again is made of steel tubing for the internal cross-bracing of the main spars of the wings, and the framework of the ailerons, the fin, the fixed tail-planes, and the elevators and rudders.

Of the two kinds of fabric employed, that covering the wings is low-grade linen of the class used on most of the enemy machines, and has a tensile strength fairly good as compared with that of British fabrics. The other fabric, used on the fuselage, tail-planes, rudder, elevator, fin and landing gear, is apparently a cheap material much inferior to British fabrics designed for a similar purpose. In both cases the dope seems to be carelessly applied. This is the first enemy machine brought down which has been found to be provided with an air-speed indicator.

ENGINES

The engine cowling is described as a particularly fine piece of work. A large scoop placed in front permits a free flow of air over the bottom and sides of the crank chamber, and by means of three large trumpet-shaped cowls at the rear a draught of air is forced against the crank case in the neighborhood of the carburetor intake. The engines consist of two standard 260 horse-power Mercedes motors, with six cylinders in line. The exhaust pipe is fitted with what amounts to a rudimentary silencer, whereas in previous machines of a similar type an open-ended exhaust pipe has been found. Each of the honeycomb radiators, which are of V section, has an electric thermometer fitted in the water inlet-pipe and wired up to a dial on the dashboard. The radiators are provided with shutters, controlled by a handle on the roof of the nacelle, which cover up a little more than a third of the cooling surface.

ARMAMENT

The bomb-racks in the covered-in passage already referred to are capable of holding five 25-pounder bombs, and under the nacelle are two large tubular frames, fitted with cradles of steel cable, and furnished with the usual form of trip gear. The racks, it is believed, would be capable of supporting a 300 kg. (660 pound) bomb apiece. The bombs carried, however, evidently vary with the radius over which the aeroplane has to operate. The large racks are not permanently attached to the nacelle, but can easily be removed as required. The bombs are released from the inside of the front cockpit, and there are seven triggers for the small bomb racks, and two levers for the large bomb trips. The bomb-sight is of the ordinary German non-precision type. Both the forward and rear cockpits are furnished with swivel gun mounts, carrying Parabellum machine-guns, and, in addition, provision is made for mounting a third in front of, and to the right of, the pilot's cockpit, where it could be managed by his companion.—Engineering Supplement of the *London Times*.

Applications of Experimental Psychology

Present-day applications of experimental psychology were dealt with recently in two lectures delivered at the Royal Institution by Lieut.-Col. C. S. Myers. The first lecture was mainly on the application of psychological experiment to industrial efficiency. Laboratory researches on mental and muscular work were described, showing the relation between rest and length of task, the importance of determining and employing the optimal load, and the various psychological factors which affect the work curve. The economical value was emphasized of introducing systematic rest pauses in the workshops and of selecting by appropriate tests employes fitted for tasks demanding special skill. There is a wide difference between the increased production due to the adoption of scientific short-hand methods of industrial efficiency and that due to the more dangerous process of "speeding up." In the second of his lectures Lieut-Col. Myers devoted himself mainly to the subject of nervous breakdown, pointing out the extreme importance of early and proper treatment of the disorder in industrial as well as in Army life. He showed how the enormous importance now attached by psychology to the influence of the feelings had come to revolutionize our conceptions of memory, or personality, and of consciousness generally; and he insisted on the necessity for continuing in peace time the special hospitals and the special psychological training of doctors which it had been found necessary to organize owing to the effects of war-strain.—*Nature*.

Scientific Efficiency in Railroad Management

Reports recently published by a prominent railroad are very enlightening as to what can be accomplished by competent scientific management. The ton-milage of revenue freight carried in 1917 exceeded the figures for 1916 by 24.49 per cent. The tonnage of freight trains increased 8.92 per cent, and the freight train milage 14.32 per cent. For 1917 four trains moved as much freight as five trains moved in 1915. The average carload increased 7.24 per cent in 1917 over 1916, and 17.30 per cent over 1915. It is stated that if the company had had to buy new cars to render this additional service, instead of increasing the work done by each old car, the cost of the new rolling stock would have been about $100,000,000. If, in addition it had had to buy locomotives in proportion to the increase in business, instead of getting more work out of each old locomotive, the cost would have been about $38,250,000.

How Bacteria in Milk Are Counted*

By F. H. Hall

UNTIL a few years ago no practicable method was known by which bacteria in milk could actually be counted. "Counts" have long been made, it is true, but these have been made by some cultural method in which the tiny plants themselves were not seen and counted, but "colonies"—little spots and circles that developed about the points where one or more bacteria were embedded in some jelly-like material suited to their growth.

Agar, a gelatinous substance derived from seaweed, has usually been the basis of this culture medium. Water, beef extract, peptone and often milk sugar are added to this, making a translucent jelly, fluid when warm, but solid when cold. A definite, small quantity of the milk sample is diluted with germ-free water to 10, 100, 1,000, 10,000 or even more times its original volume and a measured amount of this dilution is placed in shallow, circular glass dishes. To this is added a much larger quantity of the warm and fluid agar; the mixture is then shaken to insure uniform distribution of the diluted milk and its contained bacteria. As the fluid agar hardens on cooling, the bacteria are caught and held wherever they happen to be. If the bacteria are single and separated in the diluted milk, then they lie well separated from each other in the hardened agar. If, as is more frequently the case, they are in groups of two to thousands of individuals, then each of these groups forms a single center of growth. These "agar plates" are placed where the temperature is right to induce the growth of the bacteria and then held for several days, usually either two days at a warm temperature, or five days at ordinary room temperatures. Bacteria multiply very rapidly, sometimes doubling in number every twenty minutes, so at the end of a few days, under these favorable conditions, each center of growth has become a mass of individual bacteria forming a "colony" large enough to be seen and counted. Unfortunately for the accuracy of this count, the tendency of the bacteria to grow in milk in masses which cannot be separated into their component individuals causes this count to be one of the number of centers of growth, rather than a count of the number of bacteria present. It has long been known that this was the case; but since there has been no available method of determining the amount of the error thus introduced, and since counts made from duplicate samples of milk agreed fairly well when made carefully, it has become the general custom to speak of these counts as counts of the "number of bacteria" in milk. So general has this custom become among American dairy bacteriologists, and so seldom is the fact mentioned that a single colony may represent *many bacteria* in the milk, not merely *one*, that "counts" of colonies and of numbers of bacteria have to most people meant the same thing.

In 1911, however, a modification of earlier and little-used microscopic methods of counting bacteria in milk was announced, which has since been perfected, and which possesses many advantages over the plate method for the counting of bacteria in unpasteurized milks, so that it is being rapidly introduced in milk inspection work Instead of counting "colonies" after their development on a culture medium, the actual bacteria are counted under a high power microscope in the original milk distributed in a thin layer or "smear" on a glass slide and dried. By the microscopic method the results can be secured within a half hour of the time of sampling the milk, and the microscopic slides, may be preserved as a record of the condition of the milk. The milk smear is cleared of fat. The bacteria are stained so that they show plainly and are killed in preparing the slide; therefore, no growth or colony development takes place.

By this method, also, the form, shape and size of the bacteria can be studied, giving much information regarding their character; and the actual numbers of the germs can be counted, whether they be alone, in pairs, in chains, or in groups. Occasionally groups are found so large and compact that the numbers must be estimated. not counted, but such groups are uncommon.

Unless some uncontrolled error creeps into one or the other counts, the counts of individual bacteria by the microscopic method greatly exceed the counts of colonies obtained by the agar plate method. Consequently, consumers and others who take an intelligent interest in the question of milk quality must be warned that as the new method comes into more common use, they may expect larger numbers of bacteria to be reported as found in milk. The actual numbers of bacteria in the milk will not be larger, but the microscopic method will give figures that represent more closely than does the plate method the number of germs really present.

*This is a brief review of Bulletin No. 439 issued by the New York Agricultural Experiment Station at Geneva, N. Y., on the Number of Bacteria in Milk, by James D. Brew and W. D. Dotterrer, with preface by Robert S. Breed.

Because of the physical impossibility of counting the hundred of thousands or even millions of bacteria which may be present in a single drop of milk, all counts are made from a very small amount of material. The final figures given, obtained as they are by multiplication of the count made, by a figure of the proper size to give results per cubic centimeter of milk, are in every case to be regarded as "estimates" rather than as "exact" counts. As estimates they are subject not only to the usual errors of estimates, but they are also subject to certain other errors which can be made plainer by a comparison with counts of more familiar objects, such as seeds.

Suppose a farmer had several quarts of accidentally mixed seeds in which there were beet, clover, timothy, lettuce and tomato seeds, each quart unlike every other in number and proportion of the different kinds of seeds; and he wished exact information regarding each quart. After thoroughly mixing them, he sows one one-thousandth of the seeds in each quart over circles containing one square rod each of clean soil, distributing them as evenly as he can. Now he can wait a few weeks to make his counts until the seeds have grown into seedling plants. He then selects a few areas each containing one square foot and counts all of the plants which have germinated from the seeds. Or, he can make his counts at once by distributing the seeds in a like fashion on white cloth, marking off areas of one square foot each upon the cloth and counting the seeds as they lie sharply contrasted against the background.

Certain errors may occur in the first count very similar to those which occur in making agar plate counts of bacteria. To make the comparison exact, we must assume that he is unable to distinguish the separate plants produced from each beet seed ball, so that all groups of beet plants are counted as if they were single plants. It may be assumed also that part of the tomato seed falls on ground that is so wet that it does not grow, although it would have done so under proper conditions; or that some of the clover seeds fall on acid places in the soil and do not germinate. Some of the seed may also have been dead when they were planted. Assuming for the moment that he wishes a count of viable seeds only, then the latter may be disregarded. The other errors will all tend to make the count too low. But, however, careful he may have been in preparing the soil for his seed count, seeds of weeds or hold-over seeds of these same kinds are liable to be present, to germinate and be counted; so his figures may be much too high. He cannot make any count of the seeds which will include the dead seeds as well as the living ones.

If, however, he should count the seeds at once, as collected on the square foot areas of white cloth, he can see how many true seeds there are in each seed ball of the beet, and can count each of the other seeds separately. If he does not have a magnifying glass, or his eyes are poor he may overlook some of the small, light-colored timothy seeds, causing underestimates of the number present. On the contrary, all of the seeds present, including dead as well as viable seeds, will be seen and counted. In some cases this may be the count desired; but in others the desired count may be one of viable seeds only. In the latter case supplementary germination tests would show wheter the error caused by the presence of dead seeds was significant.

The comparison between the difficulties met with in making satisfactory counts of these mixed seeds in the two ways just described are so nearly identical with those met with in making counts of bacteria by the agar plate and the microscopic methods that it will require very little explanation to make these difficulties clear. Who can doubt, however, were the two methods mentioned above the only ones by which a farmer could compare and count his seeds, that he would use the one in which the could see and count the actual seeds rather than the one by which he had to wait a considerable time and estimate the number of seeds from the plants produced? And this would be especially true if the error introduced by the compound nature of the beet seed balls was a large one. By the time the seeds have germinated and the plants appeared it might be altogether too late to use the knowledge in selecting seeds for the season's planting. Moreover, if the counts were to be used as standards for judging the quality of the seed from the commercial or the control standpoint, many disputes over the counts could be prevented and fraudulent practices stopped by the preservation of the samples of seeds; while the germinated seeds could not be preserved.

During the past few years some work done by the Bacteriological Department of the Station has given a good opportunity to compare the "counts" made by the two methods of counting bacteria, and to analyze them in such a way as to determine which of the errors discussed above are really important in making routine counts of bacteria in milk. The samples, 643 in number, were taken in the morning from cans brought to the City of Geneva for its milk supply, and were about equally distributed between night milk, usually about 16 hours old, and morning milk, not more than four hours old. The samples were brought directly to the laboratory, and plates for the agar counts and slides for the microscopic count were prepared as quickly as possible under conditions which made the resulting comparisons fair ones. The plates were held for five days at room temperature and counted; then placed for two days at a higher temperature and counted again. Usually the latter count was the higher, owing to the development of new colonies from bacteria which do not grow at the lower temperature; and the higher count was used. Only "colonies" could be counted on the plates; and there was no way of telling whether these had developed from single bacteria or from many. Under the microscope the bacteria could be plainly seen, and two kinds of counts were made; one, of the whole number of individual bacteria, and the other, of the groups of bacteria. In the "group" count each individual separated from all others was counted as a "group," as well as the real groups of two or more bacteria.

If no irregularities occurred in the counts due to the presence of dead bacteria, or of organisms that failed to grow under these conditions, or to extra colonies on the plates developed from contaminations, or like things, then the counts of "colonies" on the plates should be greater than the number of "groups" and less than the number of individual bacteria. This proved to be the case in more than half of all of the counts (54 per cent, or 345 out of the 643 samples). If, however, all of the counts in which the number of individual bacteria was less than 30,000 per cubic centimeter are excluded (200 in number), nearly three-fourths of the remaining counts (71 per cent of the 443 samples) show this normal relationship. These figures indicate then that the chief reason why agar plate counts tend to be smaller than the microscopic counts is because the bacteria exist in the milk as groups more frequently than as single individuals; and that irregularities in counts due to other causes are less important than those due to the clumping of bacteria.

Because of the importance of this effect, a further study was made of the average size of the "groups" of bacteria found in the milk, this being easily determined from an examination of the microscopic preparations. Thus, 3,600 groups selected at random from milk of all grades were found to contain an average of 11.8 individuals; but these groups varies greatly in average size according to the type of bacterium. Thus "groups" of bacteria of the ordinary lactic acid types were found to be of small size, containing an average of only 3.1 individuals; while those of the streptococci (organisms which occur commonly in milk, frequently being derived from cows with garget) showed "groups" containing an average of 33.7 individuals. The average size of the "groups" in 580 of the 643 samples was 7.9; but there seemed to be a tendency for the size of the "groups" to vary with the grade of the milk. The better grades of milk containing very few bacteria showed "groups" containing an average of 2.2 individuals. The "groups" increased in size from this to an average of 12.9 individuals, and then again decreased to an average of 5.6 individuals as the bacteria developed in number and there came to be more than 10,000,000 of these organisms for every cubic centimeter (about one-third teaspoonful). In the making of the agar plates the samples of milk are diluted with germ-free water from 10 times to 10,000,000 times or more and these groups of bacteria are more or less broken apart; but they are never so broken apart that the resulting colonies each represent a single bacterium. In the making of the "smear" on the microscopic slide on the other hand, only a small portion of milk is taken, but this is not diluted, so the bacteria remain in groups as they were in the original sample. It has thus far proved impossible to control or measure the effect of the breaking of the groups in such a way that it is possible to correctly estimate from the plates what the total number of individual bacteria would be as seen under the microscope; nor to reverse the process and tell from a microscopic slide what the probable agar plate count would be in the case of individual samples of milk.

A few cases occurred (19 per cent, or 123 samples out of 643) in which the colony count did not even equal the "group" count, to say nothing of the individual count. Why is this? It must be remembered that to form colonies on the plates the bacteria must grow. To grow they must be alive, and even if alive must find conditions suitable for growth, just as in the case of the seeds. Bacteria are plants, and die as do other living things. The question, therefore, arises whether any of the discrepancies between the agar plate and the microscopic counts may be due to the presence of these dead bacteria. If such were present in the samples examined they must be included in the comparatively small group of samples where the plate count was smaller than expected. That the presence of dead bacteria was not the cause of all or

Southern California Edison Company

even a majority of the 123 counts of this type, is indicated by two things; first, that bacteria almost invariably thrive and grow rapidly in fresh milk, and second, that the same effect is produced by the presence of living bacteria which do not find conditions suitable for growth on the agar even where conditions are favorable to their growth. Every gardener knows how difficult it is to get every seed to grow. Just in the same way, bacteriologists have found it impossible to so prepare a culture medium as to make it suitable for the growth of all bacteria. So well known and common is this effect that it is reasonable to assume that this played the larger part in causing the 123 samples to show the low plate counts. In discussing the counts of seeds it was pointed out that hold-over seeds might grow and thus increase the count. In the series of 643 counts there were 175 samples (27 per cent) in which the plate counts were larger even than the individual counts as made under the microscope. In a very few instances the discrepancy was very large. Yet a careful renewed search through the microscopic preparations failed to show any such large numbers of bacteria as were indicated by the agar plates. The most natural explanation of these irregulatities is that extra colonies developed on the plates from bacteria which got into them from outside sources, and this was taken to be the case until it was noticed that all but 32 of the 175 counts were made on milk samples containing less than 30,000 individual bacteria per cubic centimeter. The localization of the majority of these counts among the milk samples containing few bacteria indicates that the majority of the counts of this type were caused through the mathematical impossibility of getting a fair average when only a small number of objects are counted, from which to estimate a very much larger number.

In making a microscopic count, it must be remembered that we do not examine the whole of the "smear" on the slide; since the field viewed under the microscope is exceedingly small and it would take altogether too much time to pass all of the thousands of fields in each smear under the microscope. Accordingly, we examine only one hundred of these fields, count the number of bacteria found, and multiply this number by the proper factor to give the approximate number per cubic centimeter. If the milk contains only a very few bacteria, we may not even find one in one hundred fields of the microscope, and so use too small a number in the computation. On the plates a much larger fraction of a cubic centimeter of milk is examined in those milks which contain few bacteria than in the case of the microscopic slides. In making comparisons of counts from low-count milk samples, the probability is that the microscopic count will be lower than it should be. This is quite probably what happened in the 143 cases in which the colony count on the agar was greater than the individual count on the slides. Many of these discrepancies were not large, and under these conditions where so few bacteria were present the microscope makes no mistake in placing it in the "good" or Grade A class even though the number of bacteria count is not quite as large as the number found by the plating method. No difficulty of this sort arises in milks containing a sufficiently large number of bacteria to be found readily under the microscope. In the case of high-count milk, the advantage of examining a realtively large amount of milk is held by the microscopic and not by the plate method. It is possible that some bacteria are so small, or stain so lightly, that they are commonly overlooked under the microscope although they would form colonies on the agar plates. There are few indications, however, of such instances, and it is believed that they are rare. The effect of such varieties if present would be to make the microscopic counts lower than they should be.

Let us return for a moment to the hypothetical methods of counting seeds. The results of the studies on the counts of bacteria show that the commonly used agar plate counts are much too low because of an error similar to the one caused by counting the beet seed balls as a single seed. They also show that there is an error of smaller size due to the presence of living bacteria which do not grow; an error similar to the one caused by the failure of some of the seeds to grow. The indications are also that where the work of making bacteria counts is carefully done, errors due to contaminations, while they do occur, are much less important than would be the similar error caused by weed seeds present in soil.

None of these errors affect the microscopic counts, the errors in this case being largely those which come from the difficulty involved in making accurate counts of objects so tiny that they can not be seen except with high magnification under the microscope. The claim which is frequently urged against making counts of bacteria microscopically based on the fact that dead bacteria cannot be readily distinguished from living ones does not prove to be of any significance in the case of fresh unpasteurized milk; because of an apparent absence or practical absence of dead bacteria in such milk. There are circumstances, moreover, in which a total count of the bacteria is of greater importance than a count of the living bacteria; and in fresh milks the dead bacteria give just as much information concerning the past history of the milk as do the living ones. Under certain special circumstances where preservatives have fraudulently been added to the milk, it is especially desirable to be able to detect the dead bacteria; a thing which cannot be done by means of the agar plating method.

Conclusions.—In view of the manifest impossibility of so perfecting either the agar plate method or the microscopic method that absolutely accruate counts of bacteria can be made; or even of controlling the errors which have been discussed, it is fortunate that comparisons of real value can be made without counts more accurate than they now are when properly made. There is no necessity for use to be able to count the bacteria in milk so accurately as to tell the difference between a sample containing 5,657 bacteria and one containing 6,756 bacteria. In looking at a distant hillside, it is not possible to count the trees thereon. Nevertheless, it is ordinarily quite possible to form an accurate judgment as to the area covered by woods, by wooded pasture, and by meadows. Such a judgment may have as great a value for the purpose in hand as would one based upon an accurate count of the number of trees per acre of land. The fact that accurate counts of the number of bacteria in milk cannot be made does not prevent the use of either the agar plate method or the microscopic method as a means of distinguishing with a satisfactory degree of accuracy between milks containing few bacteria, a medium number, and a large number. The fact that this is all that is necessary for commercial and control work has been shown in the inspection work which has been done for the City of Geneva during the past three years, a description of which will be given in a forthcoming bulletin.

It is evident from all of this work that popular ideas of the number of bacteria in milk, based as they are upon the counts made by the plating method, must be revised. The results obtained by the microscopic method of counting bacteria in milk show these to be much too low.

Geese as Flesh-Producers

DURING the food crisis every consideration should be given to the breeding of geese, which may be justly described as wonderfully economical flesh-producers, whilst the fact that goslings are not only very hardy, but may be "orphaned" or taken from the hen at a fortnight, is deserving of note. Waste land, commons pastures, golf links, parks, football grounds, and even race courses, may well be utilized this season as rearing-ground. Vegetarians almost from the first few weeks, such birds find most of the food on pastures and stubbles, whilst their marvellous grazing properties invariably improve all land they are allowed to forage on if restricted to small flocks. A choice may be made between the Embden (white) and the Toulouse (gray). The former is preferable as a rapid grower, and fattens more quickly for the table, whilst the latter is the best layer. Embden geese grow to an immense size, having a broad body, long back, and solid, wide breast. In suitable surroundings such birds reach 28 pounds to 30 pounds at maturity, but good-sized, meaty "green" geese can be fattened for the table at from ten to twelve weeks. For utility purposes the Embdens is often crossed with the Toulouse, which makes a very marketable bird. Most geese commence laying in February, and by the end of April will have laid about twenty to thirty eggs, which may be incubated under broody hens or hatched successfully in incubators. The period of incubation is thirty days. When permitted, geese will hatch and brood their own eggs. It is, however, important that spring hatching should be carried on as far as possible, so that the young goslings may take full advantage of fresh grass and herbage before the warm weather arrives. Accrimonious weeds, such as buttercups, etc., are eagerly devoured. Goslings, thrive rapidly in the earliest stages when fed on biscuit-meal, well scalded, and dried off with middlings or Sussex ground oats; whilst boiled rice or cracked wheat, dried with pea meal and middlings, is excellent. Waste or refuse of any kind may be utilized. Clover-meal, also greenstuff, lettuce and cabbage, should be mixed in all food given. Brewer's grains, boiled potatoes, swedes or mangolds, may be given as a change.

Young birds make rapid growth if protected in the early stages from rain and bad weather with good, dry housing. Vegetables should form their principal diet from the first month. Oats or grain which has been soaked in water is a favorite feed after the day's foraging. Goslings or geese always demand as much liberty as possible, and rearing should not be attempted in closely confined spaces. It is claimed that such quick flesh producers consume no food fit for human consumption. It is important that the parent stock should have age on one side of the union. Three geese and one gander will suffice for a breeding pen. It may be added that ganders are kept many years for breeding, whilst eggs should not be incubated from geese under two years old. For successful breeding and rearing stock birds should be kept lean and vigorous, and never allowed to become fat. Any open-fronted, spacious building or roomy shed, about 4 feet high, if well bedded with dry litter, will answer for geese, which may be classed as the hardiest of all feathered stock. Mention should also be made of the smaller Roman geese, which carry good breast meat, have small offal, and an absence of fat.

Poultry-keeping should always be closely associated with small holdings, allotments, and even ordinary gardens. If hens are daily supplied with succulent green food, such as vegetables and root crops, they will succeed even better than those given grass runs. All poultry-houses should have two or more runs provided to grow crops of food for the birds. Successive croppings can be easily arranged to permit fresh land for the poultry. Movable fencing, either wattled hurdles or wire netting, is advised. Poultry have suffered in the past from too liberal quantities of concentrated foods, such as grain and if vegetables, root crops, and green food are regularly increased egg yield follows. Lettuce and onions will be found the quickest growing succulent green food. Successive sowing of lettuce until autumn is advised. Cabbages or kale can be easily grown by all classes of poultry-keepers, and will provide excellent food for winter and summer, whether given raw or cooked and mixed in soft mash. Cabbages are usually a profitable crop to grow, whilst sprouting kale is excellent as winter feed. Swedes and mangolds are most useful roots to grow on any land adjacent to poultry, and no cheaper food can be supplied to egg producers. The sunflower is also a most suitable crop, and a sunflower plantation will be found an ideal rearing-ground for young chickens. Even the dried leaves of sunflowers can be mixed in the wet or dry mash. Wheat, oats, buckwheat, linseed, hempseed, rye, peas, and beans may also be favorably considered.—*London Daily Telegraph.*

Fuel Economy

WE realize that our present method of using our coal resources is terribly inefficient. We know that in the conversion of the chemical energy of coal into mechanical or electrical energy, we have to pass through heat energy and thereby submit to the excessively low efficiency of transformation from the low-grade heat energy to the high-grade electrical energy. We get at best 10 to 20 per cent of the chemical energy of the coal as electrical energy; the remaining 80 to 90 per cent we throw away as heat in the condensing water, or worse still, have to pay for getting rid of it. At the same time we burn many millions of tons of coal to produce heat energy, and by degrading the chemical energy into heat, waste the potential high-grade energy which those millions of tons of coal could supply us.

It is an economic crime to burn coal for mere heating without first taking out as much high-grade energy, mechanical or electrical, as is economically feasible. It is this feature, of using the available high-grade energy of the coal, before using it for heating, which makes the isolated station successful, though it has every other feature against it.

Assume we use 200 million tons of coal per year for power, at an average total efficiency of 12 per cent, giving us 24 million kw. (referred to 24-hour service), and use 200 million tons of coal for heating purposes, wasting its potential power.

If then we could utilize the waste heat of the coal used for power generation, even if thereby the average total efficiency were reduced to 10 per cent, we would require only 240 million tons of coal, for producing the power, and would have left a heating equivalent of 216 million tons of coal, or more than required for heating. That is, the coal consumption would be reduced from 400 million to 240 million of tons, a saving of 160 million tons of coal annually.

Or, if from the 200 million tons of coal, which we degrade by burning for fuel, we could first abstract the available high-grade power, assuming even only 5 per cent efficiency, this would give us 10 million kw. (24-hour rate), at an additional coal consumption of 10 millions tons, while the production of the 10 million kw. now requires 100 million tons of coal, more or less, thus getting a saving of 90 million tons of coal; or putting it the other way, a gain of 9 million kw.—12 million horse-power 24-hour service, or 36 million horse-power for an 8-hour working day.

It is obvious that we never could completely accomplish this; but even if we recover only one quarter, or even only one-tenth of this waste, it would be a vast increase in our national efficiency.—From a paper by CHAS. P. STEINMETZ on "America's Energy Supply" in the *General Electric Review*.

The Diamond*

Theories and Experiments in Forming Artificial Gems

By Sir Charles Parsons, F.R.S.

MANY theories have been advanced to account for the origin of diamonds, but I propose on this occasion to confine myself to what has been done in the way of systematic researches and investigations on this subject, and to consider whether it is possible to arrive at reliable and definite conclusions based on adequate foundations.

Henry Moissan must be credited with having been the first experimenter to make, and to identify with certainty, genuine artificial diamonds. In the "Fours Electrique," published in 1897, his researches and experiments are very fully described in minute detail. He generously alludes to the previous experiments of Marsden, published in the Proc. R.S., 1880-1881, and ays that he was the first to observe that if silver is

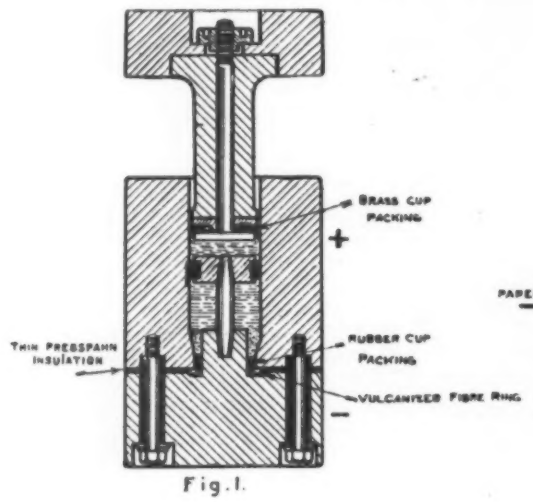


Fig. 1.

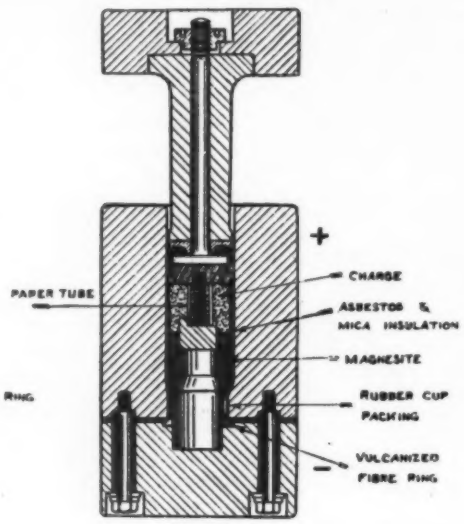


Fig. 2.

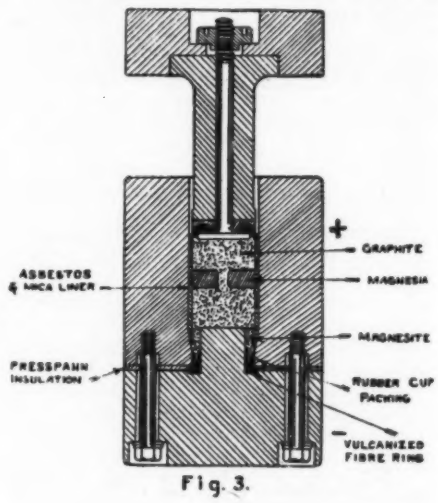


Fig. 3.

melted in a carbon crucible and raised to the melting point of steel, on cooling, black diamond is sometimes found in the center of the ingot. He, moreover, states that he has repeated the experiments of Marsden and found that when a small mass of silver is quickly cooled, a satisfactory yield of black diamond results, but that transparent diamonds are never produced in silver. Moissan further adds: "The work of Marsden is of the highest interest, because he observed quite correctly the great number of different crystallized products which may be formed at the solidifying point of silver when it gives up its oxygen, alumina, silica of carbon, etc." Moissan in 1892 developed the electric furnace and applied it to his classical experiments, which resulted in the production of minute transparent diamonds in the form of small ingots of iron, and also black diamonds in conventional ingots of silver, when highly heated and quickly cooled in water or in chills. Moissan attributes the formation of the diamond in silver and also in iron to the compressive forces produced by the contraction of the outer layers and the dilation of the nucleus when setting.

What occurs in a mass of iron so treated, I propose to discuss at some length, and to lay before you evidence that the gases occluded in the metal are the real cause of the production of diamond, and not the bulk pressure as has been previously supposed. We shall see that the weight of diamond in an ingot of iron has in one case reached 1÷20,000 part of the weight of the ingot, or the molten state on cooling. Crookes in the same lecture also stated: "It is certain from observations I have made, corroborated by experience gained in the laboratory, that iron at a high temperature and under great pressure —conditions existent at great depths below the surface of the earth—acts as the long-sought solvent for carbon, and will allow it to crystallize out in the form of diamond. There is no *prima facie* reason against this view. The calories evolved in the combination of graphite and oxygen are about ½ of one per cent less than those evolved in the combination of diamond and oxygen, indicating that graphite at ordinary temperature is, to this extent, the stable state. The bulk pressure which has operated in some of our experiments would, however, seem to have been amply sufficient to turn the balance in favor of diamond instead of graphite. The uncertainty, on the other hand, as to the compressibilities and specific heats of the allotropic forms under high pressures and at high temperatures renders speculation of little value as to what may occur at the melting point of carbon. All we know is, that up to the pressures and temperatures reached in our experiments no indication of a change from graphite to diamond has been produced.

I will now briefly describe some of our experiments which seem to bear most directly on the subject. Before doing so it is desirable first to describe the apparatus employed.

The first experiments were made in 1886 to 1888 under an 80-ton press and with current supplied from a turbo-generator of 35 horse-power; the results were given in a paper to the Royal Society in 1888. The experiments were resumed in 1907 with a new equipment which consists of a 2,000-ton hydraulic press and a storage battery of 360 kilowatts normal output. The battery can be coupled for 2, 4, 8, 16, 48 volts as required, and the mains and main switch can carry currents up to 80,000 ampères to the hydraulic press, which is placed by itself in a small strong house, partly below ground, with walls of 2 ft. thickness reinforced with steel bars—the door is of steel 3 in. thick—the roof is of light galvanized iron. The molds under the press are further enclosed by 2 in. thick telescoping steel rings raised into position by steel ropes and counterweights. These precautions, as experience proved, were necessary as several violent explosions occurred which cracked the steel rings and blew off the roof. A charge of iron and carbon when confined and raised to a high temperature may be very violent if suddenly released by the melting of the pole pieces. A steel mold of 9 in. diameter was first used, but smaller molds of 4 in. and 2 in. diameter have given satisfactory experiments and are more easily and quickly repaired and admit of higher pressures under the press. (Fig. 1-3.) We will first consider the experiments on carbon and compounds of carbon when heated under presure by means of a central conducting core through which an electric current is passed.

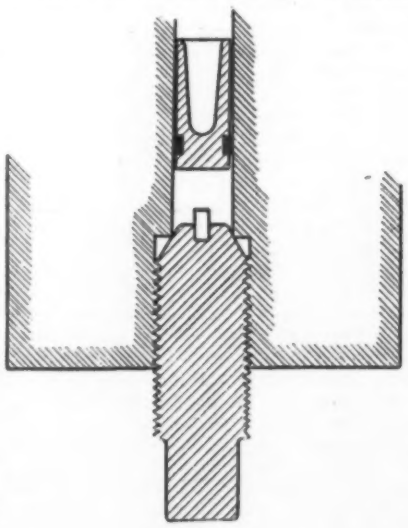


Fig. 5.

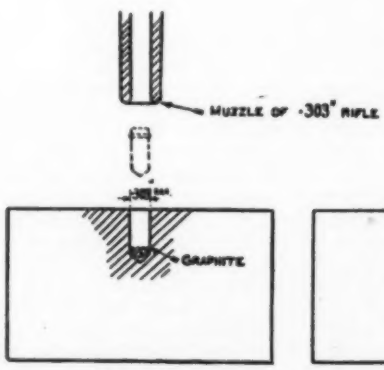


Fig. 6.

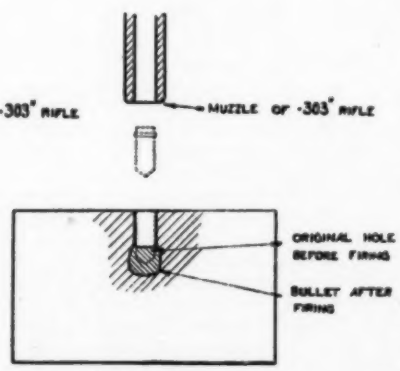


Fig. 7.

Fig. 4.

The result of treating benzine, paraffin, treacle, chloride and bisulphide of carbon, etc. under pressures up to 4,400 atmospheres resulted in the production of a soft coating of amorphous carbon on the heating rod, and when the current was very intense the carbon rod and the contiguous layer were transformed into graphite. In one experiment several pounds of carbon dioxide snow were added to the charge, which consisted of magnesia, and was so arranged that evap-

*Institute of Metals. May Lecture, 1918. From a report in *The Engineer*.

oration of the heating carbon rod took place in an atmosphere of carbon dioxide and carbon monoxide, under a gaseous pressure of 4,400 atmospheres, the condensate resulting being soft graphite. Upwards of 200 chemical reactions arranged to deposit carbon were tested under high pressure and central heating. After each experiment samples were taken from various parts of the charge and carefully analyzed for diamond, the methods of the analyses

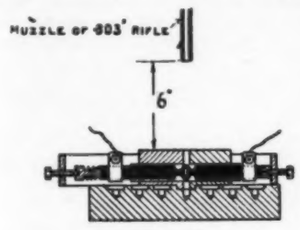


Fig. 8

generally following those of Moissan and Crookes. Small residues of diamond occasionally occurred, but they appeared to be associated with the presence of iron in the charge, whether introduced intentionally or from the melting of the pole pieces, short circuits, or from other causes. On the whole, there was no evidence that diamond had been produced by any of the chemical reactions, some of which were violent and caused explosions, and expanded the container. Some were endothermic, such as carborundum and sodium carbonate, which produced a gray solid which detonated.

We now pass on to consider the experiments designed carefully fitted to the barrel of a duck gun of 0.9 in. bore; the piston was flat in front, lightened out behind and fitted with a cupped copper gas check ring, the cup facing forward; the total travel of the piston was 36 in. To the muzzle of the gun was fitted a prolongation of the barrel formed out of a massive steel block, the joint being gas-tight. The end of the bore in the block was closed by a screwed-in plug made of tempered tool steel, also with a gas-tight collar. A small copper pin projected from the center of the plug to give a record of the limit of travel of the piston. The gun was loaded with 2 drachms of black sporting powder, which amount had been calculated from preliminary trials. The barrel in front of the piston was filled with the mixture of acetylene and oxygen. (Fig. 4 and 5.) It was estimated that this mixture would explode when the piston had traveled about half-way along the bore; when fired the piston traveled to within 1/8 in. of the end, as had been estimated, giving a total compression ratio of 288 to 1. As a result it was found that the surfaces of the end plug, the fore end of the piston, and the circumference of the bore up to 3/8 in. from the end of the plug had been fused to a depth of about .01 in., and were glass hard, the surface of the copper pin had been vaporized, and copper sprayed over the face of the end plug and piston. The end plug, which had been hardened and tempered to straw color, showed signs of compression, and the bore of the block for 3/8 in. from the plug was enlarged by .023 in. in diameter, both indicating that a pressure above 15,000 atmospheres had been reached.

A little brown amorphous carbon was found in the chamber, which was easily destroyed by boiling sulphuric acid and niter, there was no diamond residue from this. There was, however, a small crystalline residue

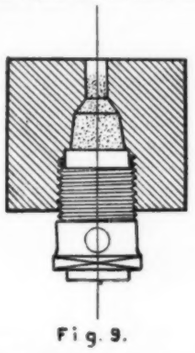


Fig. 9.

the limit of incandescence by an electric current, and the shot fired through it into the hole at the moment the carbon commenced to vaporize, as observed in a mirror from without. Also an arc between two carbons was arranged just over the hole, and the shot fired through it. (Fig. 8.)

Of all the experiments only two yielded a reasonable amount of diamond residue, one made with graphite wrapped in tissue paper, the bullet, however, in this

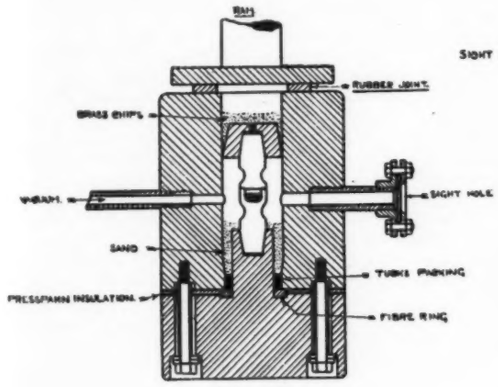


Fig. 10.

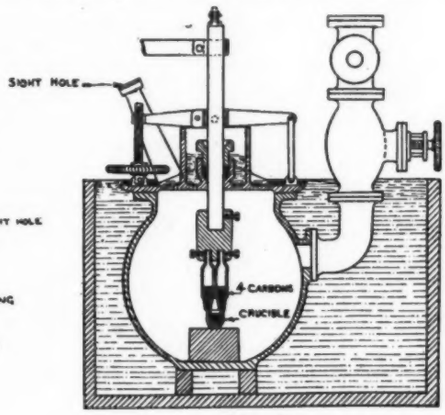


Fig. 11.

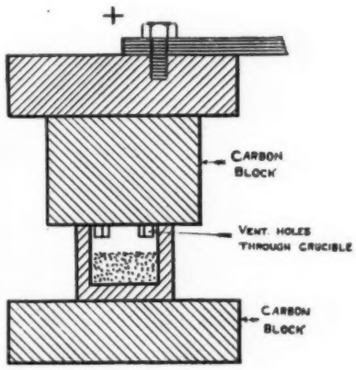


Fig. 12.

to melt carbon in bulk, and I deal with them in some detail because so much prominence has hitherto been given to this aspect of the question. The barriers used were composed of quick-lime, marble, titanium oxide, or magnesia calcined in the electric furnace; of these magnesia gave the best results, being the more slowly converted into carbide. Intense heat was applied in one experiment for 5 sec., but sufficient in amount to melt the graphite core six times over, the only result being a slight alteration of the structure of the graphite. Threlfall independently came to the conclusion from his experiments at about the same time (1907), that under 100 tons, or 15,000 atmospheres pressures per square inch, graphite, electrically heated, remained graphite. It appeared, however, desirable further to investigate the possibility of carbon losing its electrical conductivity when approaching its melting point, as alleged by Ludwig and others, and of shun ing the current from itself on to contiguous molten layers of the insulating barrier surrounding it. There had, however, been no indication of such a change having occurred, even momentarily; it rather seemed that the graphite core had been partially vaporized and condensed in the cooler parts of the charge. The experiment was, however, repeated with rods of iron and tungsten imbedded in the core, so that should the temperature of volatilization of the metals under a pressure of 12,000 atmospheres exceed that necessary to liquefy carbon under the same pressure, the presence of these metals might produce a different result. No change, however, occurred, though in one experiment the pressure was raised to 15,000 atmospheres. A different method of atta.. was then arranged which would ensure that carbon should be subjected to an extremely high temperature concurrently with high pressure, obtained by the rapid compression of the hottest possible flame, that of acetylene and oxygen, with a slight excess of the former to provide the carbon. The arrangement was as follows: A very light piston made of tool steel was from the melted layer of the end plug, from which was isolated one non-polarizing crystal, probably diamond, but too small to identify with certainty. Considering the light weight of the piston and the short duration of the exposure to heat, the small diameter and volume of the end clearance space, the effects would seem to indicate that a very abnormal temperature had been reached, many times greater than exists in the chambers of large guns. There was, however, no evidence of any melting and recrystallization of the carbon present. A calculation made by Mr. Stanley Cook, based upon the ratio of compression and a final pressure of 15,000 atmospheres, indicates that a temperature of between 15,250 deg. Cent. and 17,700 deg. Cent. was reached, the exact temperature depending upon the amount of dissociation or combination existing between the elements at the time.

It seemed desirable to try the effect of still higher pressures, so a rifle, .303 bore, was fitted with a specially strong breech mechanism by Rigby, capable of withstanding a charge of cordite 90 per cent in excess of the service charge.

The gun was fixed with its muzzle 6 in. from a massive block of steel, in which a hole, .303 diameter, had been drilled to a depth somewhat greater than the length of the bullet, and in alignment with the bore of the gun; cylindrical bullets of steel, with a copper driving band, were chiefly used, shorter than the service bullet, and about one-half of the weight, some with cupped noses to entrain material, some with coned noses to match the bottom of the hole in the block. (Figs. 6 and 7.) The velocity with 90 per cent excess charge was estimated to be about 5,000 ft.-seconds. The substance to be compressed was placed either at the bottom of the hole when a conical-nosed bullet of mild steel was used, or over the mouth of the hole when a cupped-nose bullet of tool steel was employed. About 100 experiments were made. The substances tested included graphite, sugar carbon, bisulphide of carbon, oils, etc., graphite and sodium nitrate, graphite and fulminate of mercury, finely divided iron and fine carborundum, olivine and graphite, etc. After each shot the bullet and surrounding steel were drilled out, and the chips and entrained matter analyzed.

Several experiments were also made with a bridge of arc light carbon placed over the hole and raised to

case having grazed the side of the hole, and thus producing some molten iron by the friction; the other with the incandescent bridge, where again some molten metal would probably occur. The residues were in all cases exceedingly small, and not more than would be produced from a very small amount of iron melted, carburized, and quickly cooled.

There was no evidence of any incipient transformation of carbon in bulk into diamond that could be detected by analysis.

The pressure on impact of a steel bullet fired into a hole in a steel block which it fits is limited by the coefficient of compressibility of steel, and with a velocity of 5,000 ft.-seconds is about 2,000 tons per square inch. Measurements made from a section through the block and bullet showed that the mean retardation on the frontal face after the impact till it had come to rest was about 600 tons per square inch.

Several experiments were made by substituting a tungsten steel block, and a hole tapering gently from .303 in. at the mouth to .125 in. at the bottom. The mild steel bullet was deformed by the tapered hole, and a greatly increased velocity imparted to the nose. Progressively increased charges were used, and even with relatively small charges the block cracked on the second round. With the 90 per cent excess charge, the block always split on the first shot, but this probably occurred after impact, and not till the full instantaneous pressure had been exerted, which was estimated to be greater than with the plain hole, probably exceeding 5,000 tons, a pressure about equal to that at the center of the earth.

In these latter experiments graphite was placed at the bottom of the hole. The analysis yielded nothing but graphite.

EXPERIMENTS ON PRESSURE IN CAST IRON WHEN COOLED

It has been generally assumed that iron rich in carbon expands on settings, and that this supposed property

is a contributory cause in the formation of diamond by increasing the pressure in the ingot.

We made several experiments by pouring iron, saturated with carbon, from the electric furnace through a narrow git into a very massive steel mold, closed at the bottom with a breech screw—Fig. 9. When cold the breech screw was easily removed, and there was no sign of there having been an appreciable pressure on the threads. Not being sure that, because of capillarity, the corners of the mold had been quite filled, a steel mandril was, immediately after pouring, forced down the git hole by a press giving a fluid pressure in the mold of 75 atmospheres. The observed pressure on the breech screw appeared not to have exceeded this pressure. Highly carburized iron, therefore, does not expand with any considerable force on setting.

We may, therefore, safely conclude that when iron is suddenly cooled, the only compressive bulk pressure that is brought to bear on the interior is that arising from the contraction of the outer layers after setting, and with highly carburized iron this can only be moderate because of the low tensile strength of the metal, and cannot exceed about 1,000 atmospheres.

Moissan observed that spherules or globules of iron with cracks never contained diamond. To such he attributed a loss of mechanical pressure; we now think that they merely provide an outlet for the occluded gases from the metal. We have made experiments by pouring highly carburized iron and alloys of iron on to iron plates, the cooling taking place from one side only, and under such conditions no diamond results; in fact, it only occurs when the ingot or spherule is cooled on all sides simultaneously so that a gas-tight skin is formed all over before the center is cooled.

Since my paper to the Royal Society, in 1907, the experiment of heating iron in a carbon crucible, and transferring it to a steel die, and subjecting it to 11,200 atmospheres, has been repeated, this pressure being many times greater than can occur in cooled ingot, it has been found that if the iron is allowed to set before the pressure is applied, the amount of diamond is much greater than if pressed when very hot, and while still molten, and that under the former condition it is about the same as when the crucible is cooled in water. The only reason that suggests itself to account for this is, that when pressure is applied, while very hot, some of the iron permeates the carbon of the crucible, and because of the greater specific heat and lesser conductibility of the carbon, the iron next to and in the carbon remains molten after the ingot has been cooled from the top by direct contact with the steel cup on the face of the plunger; thus when cooling, the occluded gases have a free exit from the ingot through the molten metal (which is pervious to gas) into the carbon of the crucible, and are not retained in the ingot to the same extent as when it has set before pressing, and is enclosed on all sides in an envelope of iron inpermeable to the gases.

These experiments, I think, it will be agreed, dispose of the bulk-pressure theory of the production of diamond in cooled iron. In fact, none of our experiments have shown that bulk-pressure has any effect whatever on the production of diamond unless in so far as it may affect the amount and distribution of the the occluded gases within the ingot. Several experiments were made to try the effect of extremely quick cooling, by transferring a crucible with a charge of iron from the electric furnace to the press and submerging it in carbon dioxide snow, and also in water, at 6,000 atmospheres—the analysis showed very little diamond. Other experiments where extremely quick cooling was effected not under pressure confirmed the view that quick cooling as such is not a factor in the production of diamond, and that carbon is not caught in a state of transition by quick cooling.

Experiments were made on oxidizing alloys of iron by superheated steam after heating in the electric furnace; large residues of crystalline oxides of the metals of the alloys resulted as had been observed by Marsden in silver, and there also was a small percentage of the residue (about 5 per cent) of very minute crystals which burnt in oxygen, and had a specific gravity of 3.5, and are, therefore, diamond.

This part of the subject appears to merit further investigation.

EXPERIMENTS UNDER VACUUM

The presence of diamond in some meteorites suggested a series of experiments conducted under various degrees of vacuum all the way to the highest obtainable.

It seems probable that in past ages some meteoric matter may have been melted by collision or rejected into space in a molten state and cooled by radiation, and that under such conditions absence, or diminution, of occluded gases might be a factor conductive to crystallization of diamond.

More than fifty experiments were made with electrical heating of a carbon crucible under vacuum. Fig. 11 shows the first container used, which was evacuated to about ½ mm. of mercury by three steam jets in series with an air pump and jet condenser.

This apparatus was subsequently replaced by a molecular air pump of very large capacity working in series with two other pumps, which could maintain an X-Ray vacuum during the whole of an experiment. Fig. 12 shows the container. The suction outlet to the pump is 18 in. in diameter.

When in this apparatus iron and alloys of iron were heated under high vacuum, the large volume of gas given off by the metal was very striking, and unless the heating was very gradual much of the metal was ejected from the crucible. It became quite apparent from the experiments that metal ejects the occluded gases slowly and absorbs them slowly. It was remarkable that in no experiment under a vacuum higher than 2 mm. was diamond ever found in the ingot in the crucible, but it was found in the ejected iron which had not fully parted with its occluded gases. Here again we have impressed on us by these experiments that occluded gases are essential to the production of diamond in cooled iron. Experiments were made under low vacuum—Fig. 10—averaging about 1 in. of mercury, the gas in the container being 95 per cent carbon monoxide. The heating up was prolonged and the cooling was effected solely by radiation and convection, and was relatively slow, occupying 15 sec. from switching off the current to the setting of the metal. Some of the diamonds produced in this way were of fair size, the largest measured 0.7 mm. in length.

Let us for a moment recur to the experiments designed to impose the greatest possible bulk pressure on carbon and also on iron. The experiments designed to melt carbon have been carried up to 15,000 atmospheres steady pressure, and to 300,000 atmospheres momentary pressure, which pressures are nearly up to the maximum possible with the materials at our disposal. Three hundred thousand atmospheres, or 2,000 tons per square inch is about one-half the probable pressure at the center of the earth—but only a fraction of one thousandth's part of the pressure at the center of large stars or also of the pressure produced by the impact of large bodies in space. By such collisions and intense heating and cooling, short or prolonged, of large masses might occur by the adiabatic compression of the central portions of the colliding bodies. Under such conditions the Moissan effect might be produced on a large scale, and if heating and cooling of iron are the only essential conditions, would result in the production of large diamonds. One source of diamond may, therefore, be attributed to prehistoric falls of meteorites. The artificial reproduction of such conditions is obviously beyond our reach. Up to the present, as we have said, the only proved source of artificial diamonds is from iron or silver intensely heated, and then cooled with more or less rapidity. I now pass on to further consideration of this question.

We have seen that the evidence is very strong, or perhaps conclusive, that the occluded gases which escape on the setting of the metal and during cooling are a vital factor, and that unless such gases are retained within the ingot no diamond results. We have further seen that great pressure on the metal when molten and cooling makes no difference in the yield, also that the retention of the occluded gases is in this case likewise essential. The experiments under vacuum have shown that if the metal has had time to lose its occluded gases no diamond occurs, so that we may conclude that under all bulk pressures on the metal occluded gases are an essential factor.

Let us consider what happens inside an ingot or spherule when rapidly cooled simultaneously on all sides. It is first surrounded by a thin coating of solidified metal, which below 600 deg. Cent. is nearly impervious to gases. As the coat thickens, layer within layer, more and more gas is ejected by the solidifying metal, and is forced inwards, the diminishing nucleus of molten metal and its semi-solidified center layer still impervious to gas receives the charge, and as this process progresses the pressure may rise higher and higher, though there may be a limit to the pressure against which the metal is able to eject gas when setting. All we, however, know is that the mechanical strength of the ingot or spherule places a limit of about 1,000 atmospheres to the gaseous pressure when concentrated into a small nucleus. In the case of some iron alloys which occlude more gas than iron, most of the spherules are split or shredded with an appearance consistent with this view.

It would seem that the chief and only function of quick cooling in the production of diamond in an ingot or spherule is to bottle up, and to concentrate into local spots within it, under high pressure, the gases occluded in the metal which, during slow cooling, would partially escape, while the remainder would become evenly distributed throughout the metal.

Crookes' microscopical examination of diamonds with polarized light supports this view. I now quote a passage from his lecture at Kimberley in 1905. He says: "I have examined many hundred diamond crystals under polarized light, and, with few exceptions, all show the presence of internal tension. On rotating the polarizer, the black cross most frequently seen revolves round a particular point in the inside of the crystal; on examining this point with a high power, we sometimes see a light, more rarely a minute cavity. The cavity is filled with gas at enormous pressure, and the strain is set up in the stone by the effort of the gas to escape."

Diamonds appear to be found in the metal after it has set. Moissan found that the diamond occurred near the center of the ingot, and he remarks that natural diamonds must have been formed in a pasty matrix, because they never show evidence of attachment to a hard body. But the most conclusive proof seems to be that we have found a diamond is rapidly corroded by highly carburized iron just before setting, so that a microscopic diamond could not exist in molten metal for a second.

On the whole I think that diamond is probably formed at a temperature of about 690 deg. Cent., one of the points of recalescence, while the metal is still somewhat pervious to gases.

A heat treatment at high temperatures in the electric furnace appears to be essential, and it is probably required to form carbides, within the mass, other than those of iron, and which react with the occluded gases after solidification. The view that carbon monoxide is the most important of the occluded gases is supported by the increased yield of diamond from iron which has absorbed much of this gas before cooling, and also by the fact of its combination with the metals, and also with silica and sulphur as carbonyls. Its remarkable action in association with iron on carborundum appears further to emphasize this view. In this connection Carpenter observed some years ago that the gases given off from cast iron at red heat under high vacua contained silica. We have seen that in rapidly cooled iron the occluded gases must be much compressed at the time the diamond is formed, and Mond has shown that pressure, in the case of iron, increases the yield of ferro carbonyl, and also is essential to the formation of the carbonyls of some other metals.

There is strong evidence to support the view that the action may take place solely between iron, carborundum, sulphur, and carbon monoxide. It is, however, probable that other metals may also be involved, and that the action is one of great complexity. It must always be remembered that the yield of diamond is extremely small, and therefore very small traces of some of the elements may suffice to satisfy the action.

I am not disposed to speculate, but may venture to suggest that it would seem probable that if a large mass of iron, alloyed with other elements, was submitted to suitable heat treatment, and after setting, but when still at a temperature permeable to gas, was subjected to carbon monoxide at a pressure of about 1,000 atmospheres for a long time that segregations might take place slowly within the mass, and diamonds in payable quantity and size might be produced. This experiment virtually consists in replacing the old metal envelope thrown around the ingot by a gaseous envelope at a superior pressure, which will not only imprison the occluded gases, but further, by the ingress of additional gas into the metal, may induce the formation of diamond throughout the entire content of the ingot.

It may be found that higher pressures than those permissible in a cooled ingot may increase the yield, and if this is found to be the case they can be easily applied.

The presence of crystals of silica, alumina and magnesia, and the spinels and purope, etc., associated with diamond in rapidly cooled iron alloys, and also when oxidized by steam, appears to have a bearing upon the presence of similar crystals generally found in association with diamond and merits further investigation. The solution which I have indicated appears to be compatible with the conclusions of Bonney that eclogite is the parent-rock of the diamond in South Africa. He says: "Thus the diamond has been traced up to an igneous rock. The 'blue ground' is not the birthplace either of it or of the garnets, pyroxenes, olivine, and other minerals, more or less fragmental, which it incorporates. The diamond is a constituent of the eclogite, just as much as a zircon may be a constituent of granite or a syenite. Its regular form suggests that it was the first mineral to crystallize in the magma." The solution we have suggested also accounts for so small an amount of carbon having escaped oxidation, for according to our view both the diamond and the eclogite have been crystallized in iron at comparatively low temperatures.

The Alterability of Aluminum*

And the Properties of Its Various Alloys

By Jean Escard, Civil Engineer, Laureate of the French Institute

THE chief factors which affect the alterability of aluminum are its *degree of purity*, its *physical state*, and the mechanical treatment to which it is subjected. Since its principal uses are connected with its chemical resistance it is important to know the conditions which render it and its alloys more or less alterable.

The liquid which attacks it most rapidly is hydrochloric acid, which dissolves it even when cold. Alkaline solutions (soda, potash), whether free or carbonated, also act upon it rapidly, forming soluble alkaline aluminates. Hence soda and strongly alkaline soaps should not be used for cleaning such household utensils.

In pure water, whether distilled or drinking water, aluminum keeps its luster indefinitely. Nitric, sulphuric, and acetic acids do not attack it appreciably when cold, but when hot the first two attack the commercial metal, which is not pure. If the latter contains even a small quantity of foreign substances it loses much of its resistance to corrosion and becomes subject to attack by air and by water. Thus traces of copper, iron, silicium, or sodium, and still more so a combination of those substances, cause a more or less rapid disaggregation of aluminum in contact with damp air, and especially with acidulated water, by reason of the electrolysis which is set up, whereby the aluminum is more or less rapidly ionized[1]. An electrolytic couple is formed and the vigor and rapidity of the attack are in direct proportion to the impurity of the metal and the acidity of the electrolyte (usually water).

Commercial aluminum prepared in the electric furnace is highly resistant to water, but the action is sufficiently perceptible to be used as a test to determine the amount of sodium contained in the metal. Aluminum powder is far more readily attacked, provided the mixture is first heated. When once started the action is very violent, liberating large quantities of hydrogen, and forming hydrated oxides of aluminum.

Oxygen has a highly irregular effect. In the compact state, in fact, aluminum undergoes merely superficial attack when heated in air or even in oxygen, but this is not true of aluminum powder. The latter, when obtained industrially, always contains an oxide due to the partial oxidation of the metal in the air at ordinary temperatures. Nitrogen also plays a part, the absorption of the gas being very important in certain cases.

Upon heating aluminum powder in air to 600° C. Kohn-Abrest found that it is partially oxidized without fixation of nitrogen, and that the oxidation rapidly comes to an end; but at 800° C. and above both nitrogen and oxygen are simultaneously fixed upon the metal until they have entirely disappeared.

The apparent inalterability of aluminum in the air is really due to the forming of a very thin, continuous and impermeable film of alumina. This, which is very adhesive and is at once reformed when the metal is laid bare, protects the latter against subsequent oxidation. It is, thanks to this, that an ingot of aluminum can be subjected to the temperature of the oxy-hydrogen blowpipe without undergoing much oxidation. To this also is to be ascribed the apparent retardation in the fusion of thin aluminum wires (Matignon), the alumina forming a protective sheath over the metal. In the powdered state this protective action ceases and the metal is attacked by air. Moreover it can be readily burned in air and still more so in oxygen. In fact aluminum is, of all known metals, the one which disengages the largest amount of heat, about 380 calories, in combining with oxygen. This reaction is employed industrially in metallurgy, in aluminothermy, and in the preparation of certain explosives.

Some twenty years ago the question of alterability of aluminum aroused active discussion, especially by Moissan and Ditte. The latter considered acid liquids chiefly responsible for the corrosion of aluminum, in spite of the presence of alumina. "Whenever," he says, "aluminum is in contact *at the same time* with the atmosphere, and with salt water, sea water, or brackish water, the metal becomes covered with a more or less compact layer of alumina mixed with other soluble or non-soluble salts. If the aluminum be not entirely freed from this coating upon being withdrawn from the liquid, by sufficient washing to remove every trace of alkaline matter, then the alteration will continue to progress. Wherever the exterior surface of the metal has allowed a trace of marine salt to penetrate the attack will slowly proceed, the more rapid the more hygrometric the oxidizing substance is, thereby facilitating chemical reaction."

More recent researches of H. Le Chatelier, Ducro, Heyn and Bauer appear to prove that the alteration of aluminum articles does not consist solely in oxidation or chemical or electrolytic attack, but most of all in a mechanical disaggregation causing the separation of the fibers, which retain individually their metallic luster; this fact is very important. Moreover accidents of this kind occur only in objects which have been excessively hard worked by hammering or rolling; they are similar to those which have long been observed in specimens of brass which have been too much hard-hammered.

The influence of hard-working has been studied in numerous objects; articles of military equipment, sheet metal and disks for manufacturing ordinary utensils, etc. Sheets of metal present great differences in mechanical resistance, and these arise not from any essential difference in chemical composition, but from the degree to which they have been hard-worked. Some of the efflorescences and corrosions observed are distributed irregularly, while others follow a definite direction, rectilinear upon the bottom of containers and curved on their walls. This clearly proves that these defects proceed from the direction of the lamination of the original sheet of metal.

To study the simultaneous effects of mechanical treatment and external agents (air, water, etc.), Heyn and Bauer made use of aluminum plates. To test atmospheric influence these were placed on a roof and protected from rain and snow by a bellglass. They were unaltered in aspect after more than 200 days of exposure. To test the effect of water some plates were immersed in distilled water, others in ordinary hydrant water; the latter contained 12 mg. of silica, 96 of lime, 12 of magnesia, 71 of carbon dioxide, 34 of sulphuric acid, and 26 of chlorine per liter. At the end of 207 d. a whitish deposit on the surface of the aluminum was brushed off. Dilute sulphuric acid was used to dissolve the residuum from the plates taken from the distilled water and dilute nitric acid for that of the others. In both cases potassium bichromate was added. These mixtures, which did not appreciably attack the aluminum gave the following results:

Aluminum is attacked uniformly by distilled water, the hard sheet metal being least attacked; the deposit is nearly pure hydrated alumina. It is seriously attacked by hydrant water. The attack is comparatively local and in all the specimens examined depended essentially on the previous treatment of the aluminum; it is maximum with hard or hammered sheets, minimum with soft or annealed sheets.

The alternate action of air and hydrant water according to current practice, causes a local attack which is less pronounced than that by water alone. The attack increases in strength in proportion to the rise in temperature and to the presence of carbon dioxide, which acts as a solvent: the attack is uniform and the more the sheet metal has been hard hammered the less resistant it is. Saline solutions, especially those with a basis of calcium sulphate (selenite waters), or characterized by a mixture of the carbonate, chloride and sulphate of calcium and silica, act with an energy directly proportional to their degree of concentration.

Hence there are really two sorts of attack: one which is regular and is manifested on the entire surface of the metal with the formation of hydrated alumina, and another which is manifested by local corrosions, blisters and exfoliations which cause a profound deterioration of the metal. One or the other is produced according to the following conditions:

1. The molecular state of the metal; the corrosions are due to the hard working of the metal and are not exhibited after annealing.

2. The nature of the water or of the saline solution (hydrant water, lime salts); the efflorescents observed, in fact, always contain a little lime and traces of silica. Hence contact with natural calcareous water is favorable to the disaggregation of hard worked aluminum.

Chemical reactions in general act only as an excitant and their principal role is to facilitate a transformation of the hard worked metal. M. Le Chatelier advises, therefore, as a remedy for this defect, the annealing of aluminum utensils (at 450° C. for example), or at any rate, the least possible amount of hard hammering.

The chemical composition of aluminum seems to have a much less important effect than the process of hard working. As for variations of temperature, such as result from the putting of utensils off and on the fire or filling them with hot liquids, these may explain, in combination with mechanical and chemical action, the mechanism of the spontaneous disaggregation of certain specimens of aluminum. By the united action of these various influences the joints of the cells, *i. e.*, of the metallic molecules, may split and separate out grains of aluminum; thus at the end of a certain period of time the metal which was originally homogeneous and compact is transformed into a granular mass causing the article to be thenceforth unfit for use.

The preceding statements show that the usages of aluminum depend chiefly upon its molecular structure in relation to the mechanical treatment to which it is subjected. For the treatment and conservation of liquid acids the metal is currently employed in as pure a state as possible. It is used in the nitric acid industry for apparatus employed in condensing, cooling, and transporting this liquid; care must be taken to keep the content of nitrogen dioxide no higher than 65 per cent of the monohydrate; *i. e.*, the percentage of nitrogen dioxide must be less than the amount which involves an attack on the aluminum at a given degree of concentration.

In the brewing industry aluminum is used for the manufacture, by soldering, of fermenting vats and tuns; it is non-alterable in contact with malts and the containers are very readily cleansed. The sheet metal thus used must be very pure; specimens which proved to be defective upon being used, and which were subsequently analyzed, were found to contain 0.7 per cent of silicon and 0.5 per cent of iron. Attempts have been made recently to replace aluminum by soldered soft sheet steel whose surface has been covered with an aluminum film by means of the Schoop process; the protective layer thus obtained is identical with sheet aluminum; only the density of the metal is increased.

Dairies also make extensive use of all sorts of aluminum receptacles. Pure aluminum is not attacked by either fresh or sour milk, red or white wines, or 10 per cent solutions of salt, iodide of potassium, sodium nitrate, potassium sulphate, chloride and nitrate of calcium. A 10 per cent solution of bicarbonate of soda, on the contrary, does attack it, as well as solutions of calcium and magnesium sulphates; the same thing holds true of a large number of mineral waters containing bicarbonates of these two metals.

Aluminum presents many advantages for cooking utensils: a very great calorific capacity, a slight power of radiation, absolute harmlessness to health and easiness to keep clean and bright.

Alluminum alloys vary in behavior according to the properties and proportions of the combining metals. The presence of certain definite constituents, corresponding to definite percentages of the various elements, seems to be chiefly concerned in the behavior of the final product. The formation of couples between the various metals and the more or less acid mediums with which they are in contact is concerned in the phenomena of attack and erosion observed.

Aluminum bronzes, or copper-aluminum alloys, likewise possess great resistance to corrosion, which renders them suitable for articles destined for domestic or for maritime use. Various tests have shown that bronzes containing 3 per cent of aluminum immersed in sea water alone behave somewhat better than Muntz metal (copper zinc, tin) and also then naval brass (brass containing 2 per cent of tin). In contact with steel they exhibit no alteration at the end of 4 months.

Tests made with pure aluminum and with bronzes containing a high percentage (99.07 to 95.26 per cent), of this metal gave the following results: the former showed a loss of 4 mg. per square cm. in 30 days; the loss ranged downward to 1.5 mg. lost by the 95.26 per cent alloy.

As we see the attack was comparatively rapid; it was even possible to observe small bubbles of gas, and a gelatinous deposit of alumina was formed around the plates experimented upon. This rapid alteration shows that it is impossible to use alloys rich in aluminum for maritime purposes. Some years ago the French government had marine sheet metal made of similar bronze, and it was found unsatisfactory in spite of the lightness and strength of construction thereby attained; the sea water caused rapid perforation of the plates wherever the paint was scraped off.

On the contrary, 10 per cent aluminum bronze has given really remarkable results in marine construction. Numerous propellers made by the English Admiralty have always proved satisfactory with regard to tenacity and the limit of elasticity and elongation while exhibiting a firm resistance to the action of the water.

It is highly interesting to compare this bronze with

*From *Revue Scientifique*.

[1] It is electropositive as regards copper.

other metals and alloys. Thus iron undergoes a loss of 4.5 mg. per square centimeter when exposed for one month, copper loses 1.3 mg., Muntz metal 0.7 mg., *bronze with 10 per cent of aluminum loses 1.5 mg.*, and bronze with 40 per cent of aluminum 0.4 per cent.

Tests made with electric couples made by the union of 10 per cent aluminum bronze with another metal proved that the former was not appreciably attacked when in contact for a long period with either iron or Muntz metal; these latter, however, were much altered.

Domestic utensils made of alloys containing a very small percentage of aluminum are very slightly altered in pure water, while Muntz metal and naval grass are not attacked at all under similar conditions. Bronzes with a high content of aluminum are not sensibly attacked by boiling water containing organic acids, and are, therefore, suitable for culinary utensils. This was proved by tests made with boiling one per cent solutions of oxalic acid and acetic acid, and a two per cent solution of citric acid. This degree of concentration corresponds to that which may possibly be found in foods. Another advantage of the aluminum bronze alloy is its beautiful yellow color which retains its luster, since it is not subject to oxidation. Le Chatelier called attention to articles made of aluminum bronze belonging to the families of old friends of H. Sainte-Claire Deville; these were as bright as when first made after 50 years of use. This alloy is superior to copper for cooking vessels because it does not form verdigris, and to nickel because it contains no arsenic.[2] Moreover it is only one-third as heavy as iron, nickel, or copper for an equal volume. In caring for it it is only necessary to avoid alkalies and hydrochloric acid, which attack it as they do pure aluminum.

Duraluminum, so called because of its hardness, is a bronze containing 93 to 95 per cent of aluminum, 0.5 to 1.5 per cent of magnesium, and 3 to 5 per cent of copper. It resembles ordinary aluminum bronzes in its resistance to corrosion. Its lightness and its mechanical resistance have caused it to be used for making certain parts of airplanes; it was also employed in the construction of the first English dirigible with entirely satisfactory results.

However, when it is possible to avoid it, duraluminum should not be placed in contact with copper or with bronze, since with these it forms couples which may in time corrode it under the influence of atmospheric agents or of certain saline or acid products. For the same reason it should preferably be riveted with iron rivets, or still better with rivets of its own material. In soldering it aluminum wire is used.

Alloys of zinc and aluminum exhibit likewise, for the most part, great resistance to atmospheric agents, and are non-oxidizable at ordinary temperatures, neither dry nor humid air transforming them. Cold dilute caustic potash and hydrochloric acid attack them more vigorously then they do pure aluminum. But the most singular chemical action is that which they display in water containing a solution of copper sulphate. The zinc-aluminum alloys, in fact, do not decompose pure water containing traces of ordinary salt, but do decompose that which contains copper sulphate. Water containing a solution of zinc sulphate (density 1.4) is decomposed much more slowly. The order and the activity of these decompositions correspond to the exothermy of the solutions, the most exothermic, zinc sulphate, being more easily decomposed then copper sulphate which is less so. Hydrogen is liberated.

The alloys of magnesium and aluminum are briskly attacked, even in the cold, by hydrochloric acid. With concentrated acid there is a projection of numerous incandescent metallic particles. All the alloys are attacked by either dry or humid air at the temperature of the tapping. The alloy with 54 per cent of aluminum is particularly unstable, a comparatively short exposure to the air producing alteration.

A solution of sodium chloride (17 mg. per liter of distilled water), is briskly decomposed by a recently filed rod of aluminum-magnesium alloy dipped in it[3], with an abundant liberation of hydrogen. In the aqueous solution of copper sulphate (density 1.1), the decomposition of the water is still more active and the sulphate is decomposed at the same time. The reaction is much more lively than with the zinc aluminum alloys, the two elements, magnesium and aluminum being energetic reducers of water.

It may be inquired whether there is not a catalytic action here, due to the precipitated copper, which facilitates the reduction of the sulphate through the excess of hydrogen and lays bare the surface of the alloy, thus permitting the attack to continue. Successive weighings of a piece of magnesium-aluminum containing 85 per cent of the latter metal proved that the liberation of hydrogen in the water is due solely to the magnesium, the aluminum merely reducing the sulphate of copper. According to P. cheux there is in fact no deposit of copper in this case, which clearly indicates the non-reduction of the sulphate by the hydrogen. It should be observed, moreover, that a non-filed magnesium-aluminum alloy with a polished and annealed surface, will be covered in about 10 hours with a very solid and adhesive deposit of copper; the alloy with 85 per cent aluminum gives a thickness of 0.09 mm.

The alloys of tin and aluminum are attacked at ordinary temperatures by caustic potash diluted with cold water, by hydrochloric acid and by humid air. The action of water is extremely curious and can be made manifest by the following experiments:

Dip into distilled water at a temperature of 150° C. a rod of tin aluminum alloy whose surface has just been filed. There will be an abundant liberation of hydrogen and of oxygen around the filed portion of the rod. This will last for a length of time proportional to the amount of wear occasioned by the filing; it will cease at the end of two or three minutes.

A filed rod composed of only one of these metals does not produce the same result. Moreover, a rod of the alloy which has not been filed, but which has been heated to a temperature similar to that produced by filing, exerts no action. M. P. cheux, the author of these observations, explains the reaction by the formation of a thermo-electric couple between the aluminum and the tin. The alloys of these two metals, immersed in cold water after filing, constitute a sort of series of minute thermo-electric couples. The molecules of tin and of aluminum being heated integrally by the file by reason of the great difference between their specific heats (0.218 cal. for aluminum and 0.0562 cal. for tin), an electromotor force is produced which is annulled when the temperatures of the two kinds of molecules are equalized by the prolonged contact in cold water. Analysis of the gases given off (oxygen and hydrogen), shows that they occur in the same proportions as when water is decomposed by an electric battery.

Distilled water at the boiling point is decomposed by a rod of tin-aluminum alloy which has not been filed, as if the annealing which takes place at 100° C. destroys the combination of the two metals on the surface of the alloy.

Water containing a slight addition of copper sulphate or zinc sulphate is likewise decomposed. With the former bubbles of oxygen are liberated and copper is deposited on the non-filed portion of the rod. It is true that a rod of either tin or aluminum alone will precipitate the copper of the sulphate, but no gas will be set free. M. Pécheux's theory seems probable, therefore, from every point of view.

Slightly different phenomena are observed with alloys of lead and aluminum: they do not decompose pure water containing traces of sodium chloride, as do the alloys of magnesium alumium, bismuth aluminum, and tin aluminum; but, like the alloys of zinc-aluminum, they decompose that in which copper sulphate is dissolved. Water in which zinc sulphate (density 1.4) is dissolved is more slowly decomposed. They are all attacked in the cold by hydrochloric acid and by dilute potash. Neither dry nor humid air appears to oxidize them in the cold.

The alloys of silicon and aluminum containing 10 per cent of silicon have a resistance to attack by the usual reagents similar to that of pure aluminum so long as the percentage of iron present as an impurity remains very low. But they are completely soluble in melted alkalies and alkaline carbonates as well as in hot and concentrated alkaline solutions. Nitric acid, on the contrary, even when hot, will not attack them except very slowly. Sulphuric acid attacks them feebly and slowly. Hydrochloric acid acts violently, with the formation of a deposit whose color varies according to the mode of preparation of the alloy. The mixture of hydrofluoric and nitric acids attacks and completely dissolves all silicon-aluminum alloys with very great violence.

[2] The presence of arsenic in the nickel comes from the composition of certain minerals of this metal, namely the arsenio-sulphides of nickel.

[3] Filed metallic aluminum is subject to scarcely any attack from solutions of sodium chloride and copper sulphate.

Effects of Cold Working on the Elastic Properties of Steel

MILD steel was subjected to cold stretching, compression, and twisting, and afterwards tested with reference to its elastic properties. It was found, contrary to accepted opinion, that cold stretching does not lower the elastic limit in compression, and the effects of cold working are probably a function of the strains and are independent of the stresses involved in the process. When a mild stell is cold worked and properly heat treated, the elastic limit may be raised more than 100 per cent when tested in the same direction as the applied strain. Tempering at 100 degrees C. to 300 degrees C., or ageing the cold-worked steel, tends to improve the elastic properties. Application of heat merely accelerates the effect of time. Cold working breaks up the coarser crystalline structure and planes of weakness, with formation of amorphous steel, and after ageing, the elastic limit is not reached until a greater stress than that at which cold working is discontinued is attained. The beneficial effect of cold working is permanent.—Note in *Jour. Soc. Chem. Ind.* on a paper by J. A. VAN DER BROEK before the Iron and Steel Inst.

The Red Sunflower

IN the issue of the SUPPLEMENT of August 3d, there appeared an interesting article on "The Red Sunflower" by Prof. T. A. D. Cockerel, accompanied by numerous striking illustrations. This article originally appeared in *The American Museum Journal* published by the American Museum of Natural History, of New York but through inadvertance proper credit was not given to the journal, as was intended. It may also be stated that the photographs from which the illustrations were prepared were made available through the courtesy of Museum authorities.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, AUGUST 24, 1918

Published weekly by Munn & Company, Incorporated
Charles Allen Munn, President
Secretary; Orson D. Munn, Treasurer
all at 233 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

Copyright 1917 by Munn & Co., Inc.

The Scientific American Publications

Scientific American Supplement, (established 1876) per year $5.00
Scientific American (established 1845) 4.00
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Munn & Co., Inc., 233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

Back Numbers of the Scientific American Supplement

SUPPLEMENTS bearing a date earlier than January 1st, 1917, can be supplied by the H. W. Wilson Company, 958-964 University Ave., Bronx, New York, N. Y. Please order such back numbers from the Wilson Company. Supplements for January 1st, 1917, and subsequent issues can be supplied at 10 cents each by Munn & Co., Inc., 233 Broadway, New York.

WE wish to call attention to the fact that we are in a position to render competent services in every branch of patent or trade-mark work. Our staff is composed of mechanical, electrical and chemical experts, thoroughly trained to prepare and prosecute all patent applications, irrespective of the complex nature of the subject matter involved, or of the specialized, technical, or scientific knowledge required therefor.

We also have associates throughout the world, who assist in the prosecution of patent and trade-mark applications filed in all countries foreign to the United States.

Branch Office:
625 F Street, N. W.,
Washington, D. C.

MUNN & Co.,
Patent Solicitors,
233 Broadway,
New York, N. Y.

Table of Contents

	PAGE
The Psychology of color-I.—By Leonard Thompson Troland	114
Permeability of Balloon Fabrics	115
Steam from Coke	115
The Lyre of the Poets.—By John Candee Dean.—3 illustrations	117
The Tamarind—By C. D. Mell.—1 illustration	117
Automatic Lighthouses	117
The Oceanographic Work of the Royal Italian Committee	118
Dust Inhalation in Mines	119
New Disinfection Process for Ships	119
A New Heat Insulating Material	119
Sugar Making in Cuba.—5 illustrations	120
German Aeroplane Design	121
Applications of Experimental Psychology	121
Scientific Efficency in Railroad Management	121
How Bacteria in Milk are Counted.—By F. H. Hall	123
Geese as Flesh-Producers	123
Fuel Economy	123
The Diamond.—By Sir Charles Parson.—12 illustrations	124
The Alterability of Aluminum.—By Jean Escard	127
The Red Sunflower	128
Effects of Cold Working on the Elastic Properties of Steel	128